Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Multiple impacts of energy efficiency in policy-making and evaluation

D8.2 Policy report on COMBI results

Grant Agreement No. 649724

Wuppertal Institut

Authors

Johannes Thema
Jana Rasch
Felix Suerkemper
Stefan Thomas

with contributions from

Johan Couder (University of Antwerp)
Souran Chatterjee (ABUD)
Jens Teubler (Wuppertal Institute)
Martin Bo Hansen and Sabine Wilke (Copenhagen Economics)
Nora Mzavanadze and Stefan Bouzarovski (University of Manchester)

Coordinated by

Wuppertal Institut

Project partners

ABUD

Copenhagen Economics CE

Universiteit Antwerpen

MANCHESTER 1824 The University of Manchester

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649724. This document reflects only the author's view. The Agency is not responsible for any information it contains.

This report is part of the project COMBI. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649724. This document reflects only the author's view. The Agency is not responsible for any information it contains.

Please cite as: Johannes Thema, Jana Rasch, Felix Suerkemper, Stefan Thomas (2018). Multiple impacts of energy efficiency in policy-making and evaluation. D8.2 Policy report on COMBI results.

Project duration: 03/2015-06/2018

Project coordination: Johannes Thema, Felix Suerkemper
Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Döppersberg 19
42103 Wuppertal

Project partners:
Advanced Buildings and Urban Design, Hungary
Copenhagen Economics, Denmark
University of Antwerp, Belgium
Manchester University, United Kingdom

Authors
Johannes Thema, E-Mail: johannes.thema@wupperinst.org
Jana Rasch, E-Mail: jana.rasch@wupperinst.org
Felix Suerkemper, E-Mail: felix.suerkemper@wupperinst.org
Stefan Thomas, E-Mail: stefan.thomas@wupperinst.org
with contributions from
Johan Couder (University of Antwerp)
Souran Chatterjee (ABUD)
Jens Teubler (Wuppertal Institute)
Martin Bo Hansen and Sabine Wilke (Copenhagen Economics)
Nora Mzavanadze and Stefan Bouzarovski (University of Manchester)

Editor
Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Döppersberg 19
42103 Wuppertal
www.wupperinst.org
Contact: Johannes Thema
Tel. +49 202 2492-186
johannes.thema@wupperinst.org

Wuppertal, May 2018

Content

List of tables

List of figures

Executive summary

COMBI objectives and approach

The COMBI project aimed at quantifying the multiple non-energy benefits of energy efficiency in the EU-28 area and incorporate those multiple impacts into decision-support frameworks for policy-making. Therefore, all multiple impacts of energy efficiency are analysed from an overall societal view in the project. The COMBI policy recommendations resulting from the evaluation outcomes are presented in this report.

COMBI draws on a *reference* scenario until the year 2030 including existing policies. By modelling 21 sets of "energy efficiency improvement" (EEI) actions, a second *efficiency* scenario was modelled amounting to additional energy savings of around 8% p.a. in 2030, and that is comparable to the EUCO+33 to EUCO+35 scenario. All figures quantified by COMBI relate to *additional* values, i.e. *additional* impacts resulting from *additional* EEI actions beyond the reference scenario as a consequence of *additional* policies. The project quantified in total 31 individual impact indicators with appropriate state-of-the-art models. Covered impacts include

- air pollution with sub-effects on ecosystems and human health
- energy poverty-related health impacts from building conditions
- productivity impacts from residential and tertiary building refurbishments
- resource impacts (material footprint, including various sub-impacts)
- macro-economic impacts (labour market, GDP and public budgets, energy prices)
- energy system/security impacts (various indicators)

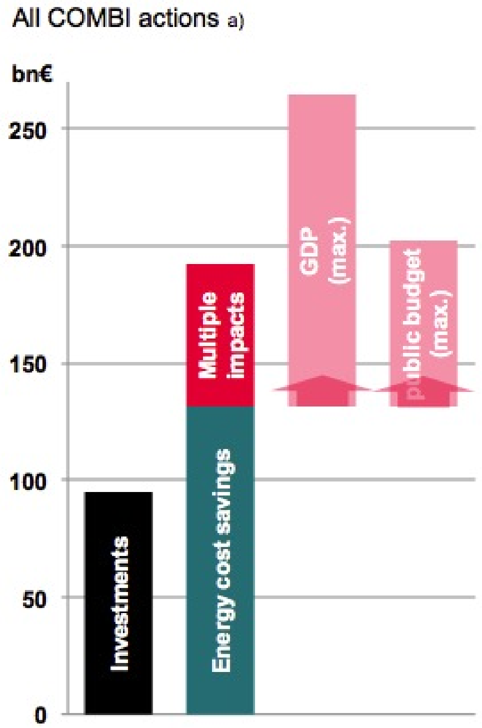
More than half of all sub-indicators were possible to monetize, but not all monetized impacts can automatically be included to a Cost-Benefit Analysis (CBA), because they may possibly overlap. Where the research team identified overlaps, we entirely excluded impacts from the CBA, resulting in conservative figures for net values, that can be interpreted as low end of the scale.

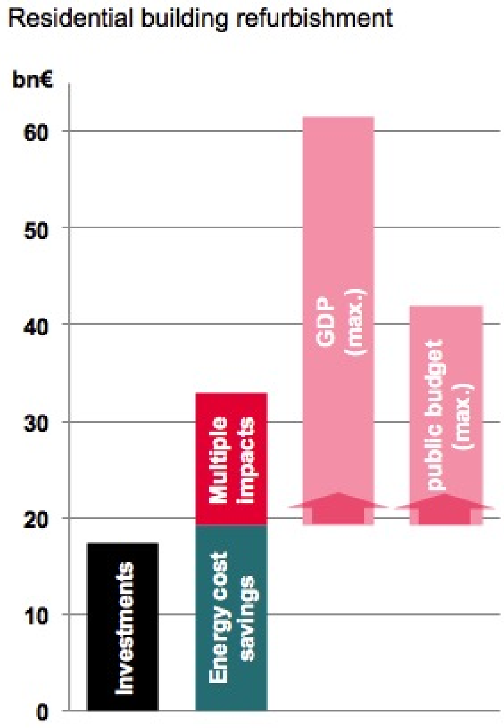
Key quantification results

Pursuing a more ambitious energy efficiency policy that leads to achieving the COMBI efficiency scenario relative to the COMBI reference will lead to **at least** the following impacts (conservative estimation, selected impacts, per year):

Air pollution	Resources	Social welfare	Economy	Energy system
>10,000 avoided premature deaths due to PM2.5 (460 mn €) and 442 due to O3 (46 mn €) 230,000 YOLLs of avoided life expectancy loss (26 bn €) 300Mt avoided direct CO_2eq emissions (17 bn €)	850 Mt savings of material resources	3,000-24,000 avoided premature deaths due to indoor cold (323 mn €-2.5 bn €) 2,700-22,300 avoided DALYs due to indoor dampness related asthma (338 mn €-2.9 bn €) 39mn additional workdays (4.7 bn €)	1% rise in GDP (+161 bn € in GDP) 2.3 mn job-years +86 bn € for public budgets Decrease in fossil fuel prices (1.3% oil, -2% coal, -2.9% gas)	Avoided generation of power from combustibles 257 TWh (11 bn € of avoided investment) Improved energy security up to 5% lower fossil fuel import costs (48 bn €)
WP3 report	WP4 report	WP5 / WP5a report	WP6 report	WP7 report

Figure: Investments, energy cost savings and multiple impacts (bn€ annual in 2030)





[a] all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of out-dated investment costs

If including only those monetized impacts to a CBA where COMBI is entirely sure that no overlaps exist, the analysis yields that annually

- for all COMBI actions (excl. modal shift and trucks), multiple impacts amount to 61 bn€ vs. 131 bn€ of energy cost savings, i.e. multiple impacts are approx. 50% of energy cost savings
- for the residential buildings refurbishment example, multiple impacts amount 13.6 bn€ vs. 19.2 bn€ of energy cost savings, i.e. multiple impacts are approx. 70% of energy cost savings

Economic impacts (aggregate demand/GDP and public budget) are not included due to *partial* overlaps and uncertain valuability (only effective, if economy with idle resources). However, those are the potentially highest impacts:

- For all actions (excl. modal shift and trucks), GDP may add value with the size of another 100% of energy cost savings, and public budget another 50%
- For residential buildings, this relation is even higher, namely 220% of energy cost savings GDP effect and 120% public budget effect

To conclude, the conservative CBA approach of COMBI yields that *at the very least*, including multiple impact quantifications to energy efficiency impact assessment, would increase the benefit side by 50–70%. But this analysis excludes numerous impacts that could either not be quantified or monetized or where any double-counting potential exists. Only including the quantified economic impacts of GDP and/or public budget would double or triple the size of multiple impacts. With further research, especially on impacts that could not be quantified or monetized and on determining the size of overlaps, so that the additional fraction of impacts can be included to a CBA, it is very likely, that multiple impacts will increase to 100% or more of pure energy cost savings.

Key policy recommendations

The COMBI results show that the multiple impacts of energy efficiency are substantial. Evaluating them as comprehensively as possible is essential for the following reasons:

- A more complete picture of the various (positive and negative) impacts of energy efficiency is a precondition for a more complete assessment of policy impacts on a number of policy targets. Reliable quantifications of multiple impacts will thus support policy makers to make the right choice in prioritising energy efficiency vs. expanding sustainable energy supply (incl. their multiple positive and negative impacts), but also in energy efficiency policy design and implementation, i.e. help selecting those instruments and targets that maximize social welfare.
- An omission of multiple impacts in cost-benefit analysis reduces the cost-effectiveness of EEI actions below their actual value and leads to an underinvestment (sub-optimal level) in energy efficiency from a societal perspective. The same is true if not all impacts are included or are underestimated. If multiple impacts are included into the assessment of policy scenarios, higher ambitions on energy efficiency targets are more cost-effective.
- Energy efficiency is a case not only for cost savings and GHG Mitigation but also for improvements in human health, environment, agriculture, and could have positive stimulating effects on the economy. Making more explicit the multiple impacts that concern policy targets of non-energy departments (e.g. health, social welfare, economy) may lead to a convergence of interest and may encourage inter-departmental and cross-sectoral co-operation in policy making to pursue common goals.
- Quantified values of multiple impacts will be beneficial for their communication and promotion to decision-makers, stakeholders and the general public in order to gain support for the implementation of respective energy efficiency policies and to increase the attractiveness of investments in energy efficiency for potential investors.
- Not the least, energy efficiency policy that helps achieve the potential will also be a good investment for the minister of finance: a budget surplus of annually up to € 85bn is much more than the necessary energy efficiency policy is likely to cost. The EU might consider (e.g. in the multi-annual financial framework and the implementation of the financial stability pact) that all Member States are able to take this prudent investment in energy efficiency policy.

1 Introduction: Multiple impacts of energy efficiency in European policy-making

1.1 Multiple impacts in the European energy policy discourse

Energy Efficiency has always been a means to achieve higher ends such as fossil fuel savings for saving greenhouse gas emissions. In Europe, with the adoption of the energy efficiency first principle under the 2012 European Energy Efficiency Directive (EED, 2012/27/EU), the first preamble already names many policy targets of the EED:

> The Union is facing unprecedented challenges resulting from increased dependence on energy imports and scarce energy resources, and the need to limit climate change and to overcome the economic crisis. Energy efficiency is a valuable means to address these challenges. It improves the Union's security of supply by reducing primary energy consumption and decreasing energy imports. It helps to reduce greenhouse gas emissions in a cost-effective way and thereby to mitigate climate change. Shifting to a more energy-efficient economy should also accelerate the spread of innovative technological solutions and improve the competitiveness of industry in the Union, boosting economic growth and creating high quality jobs in several sectors related to energy efficiency. (EED, 2012/27/EU)

The multiple impacts are thus as much a motivation for European policy action on energy efficiency as saving energy costs – but in the discourse and negotiations between institutions and national representatives, they are often out of sight. This may be because the causal link from investments in energy efficiency to the impacts is often very complex and indirect, so effects cannot be seen immediately.

In 2014, the IEA published a widely recognised book on "Capturing the Multiple Benefits of Energy Efficiency", the first comprehensive collection of knowledge and approaches on their quantification.

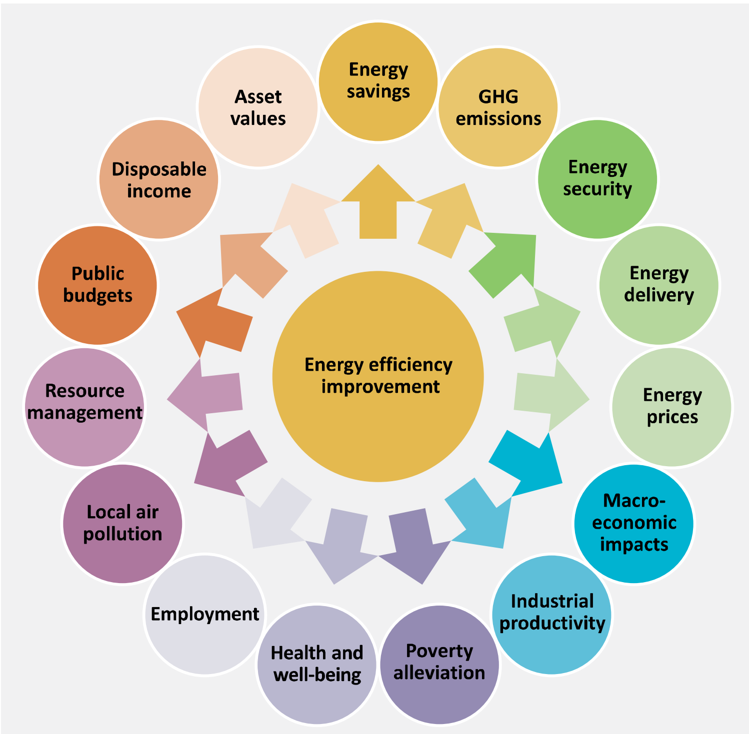


Figure 1: Quantification and monetization of 32 impacts for 21 energy efficiency improvement actions for all 28 EU Member States

Note: This list is not exhaustive, but represents the most prominent benefits of energy efficiency identified to date. Source: IEA (2014).

Early reports already quantified certain impacts for certain sectors, e.g. the buildings sector (Renovate Europe 2012). Since then, efforts to quantify multiple benefits at European level have increased, also on a national level, e.g. for Sweden (Copenhagen Economics 2016) or Thailand (Suerkemper et al. 2016). As part of the 2016 "Winter Package" of EU energy legislation drafts issued by EU-Commission, the EED and Energy Performance of Buildings Directive (EPBD 2010/31/EU) are currently redrafted. In this context, the usual impact assessments are done – and in this case also contain numerous other impacts such as economic ones (labour market, GDP), energy imports and air pollution. In 2017, a separate EU-Commission report (Cambridge Econometrics et al. 2017) quantified additional impacts of energy efficiency policy.

The topic still is on the agenda: In March 2018, the IEA followed up with a dedicated high-level workshop. However, it remains a big task for science and policy to understand causality and size of multiple impacts, so that they can really be put at the heart of policy decisions.

Institution	Year	Key publications on multiple benefits
iea International Energy Agency	2014	[Capturing The Multiple Benefits of Energy Efficiency]
European Commission	2016	[Impact Assessment to the recast of the Energy Efficiency Directive (+ Annex)]
European Commission	2016	[The macro-level and sectoral impacts of Energy Efficiency policies]

Two main reasons for quantifying and monetising as many as possible multiple impacts are frequently named – again by representatives from the European Commission (Paul Hodson, Serena Pontoglio) and other experts at the COMBI final conference:

- The possibility of including Multiple Impacts into the assessment of policy scenarios renders higher ambitions on energy efficiency targets more cost-effective.
- Multiple Impacts that concern policy targets of non-energy departments (e.g. health, social welfare, economy) may lead to a convergence of interest. Therefore, inter-departmental cooperations should be forged to pursue common goals.

1.2 Energy Efficiency: a means to multiple ends

For ambitious energy efficiency policy to gain support, it will often be crucial to identify other policy areas, which try to achieve other objectives by (inter alia) promoting actions to increase energy efficiency – or which have converging policy targets supported by energy policy action. Almost all policies can be expected to, intendedly or unintendedly, affect energy demand in a positive or negative way, yet are seldom analysed in this way. Cox et al. (2016)[1] terms this "invisible energy policy". Many examples are conceivable, e.g.:

1 https://www.academia.edu/30027209/The_impacts_of_non-energy_policies_on_the_energy_system_a_scoping_paper

- Policies to alleviate poverty could employ energy efficiency improvements to reduce energy expenditures,
- policies to foster public health could improve indoor air quality by supporting energy efficient ventilation systems,
- "cash for clunkers" policies aim at stimulating the economy during a downturn and may converge with energy efficiency policy if incentivising the purchase of more energy efficient products,
- a large array of air quality policies have the reduction of air pollutants as their objective; most promising solutions can be found in the energy / energy efficiency area.

These non-energy policies have in common, that they name another impact, or benefit, as a rationale for investing in energy efficiency. This means, energy efficiency is one means to address various policy targets – among others. The energy and climate community needs to understand that for other policy areas, energy savings are not at the heart of the argument. Recognising this and at the same time identifying where policy objectives converge (be it health, the economy, environment or climate), may be the basis for joining forces.

If energy policy makers identify where their policy objectives converge with other policy areas, this may be a good starting point for joining forces to promote energy efficiency policies and measures as the mean that helps both (or more) areas. Multiple impact analysis contributes to the identification of such areas.

1.3 Existing cases: Multiple impacts as main motivation for policy making

In several cases multiple impacts had already been the main motivation for the implementation of energy efficiency policies implemented either by institutions directly responsible for energy policy or by departments, ministries or organisations not responsible at all for energy policy, but still promoting energy efficiency due to the associated multiple benefits. A selection of such case studies are presented in the following.[2]

The first example illustrates a multiple benefits policy from an energy department, which aimed not only at energy savings, but also at multiple benefits.

---

2 Further policy examples aiming at multiple impacts of energy efficiency not described in this report:

- Energy Company Obligation (ECO) (UK) (formerly Warm Front Scheme): ECO obliges UK's biggest energy suppliers to fund the installation of new boilers and / or insulation for low income households and districts. http://www.affordablewarmthgrants.co.uk/grants/warm-front-scheme.htm
- Energy poverty programme (France): On 12 July 2010 a law for energy poverty was established in France. Furthermore a national energy poverty observatory (ONPE – ob-servatoire nationale de la précarité énergétique) was introduced with subscribers from different ministries and a national fund for building renovation. https://www.precarite-energie.org/-Formation-en-ligne-.html
- AVoided Emissions and geneRation Tool (AVERT) (USA): An EPA tool that estimates the emission benefits of energy efficiency and renewable energy policies and programs. https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert#who
- Green and Healthy Homes Initiative (GHHI) Baltimore: GHHI is an NGO that aims at providing holistic approaches to produce "green, healthy and safe homes" especially for children to improve health, economic and social outcome for families in the USA. They try to implement i.a. energy efficiency measures aiming at health benefits. To this end, they provide a variety of services in the range of advices, assessments, trainings, interventions. The NGO counts with the support of different industrial sectors, ministries/departments, the covenant of Mayors, universities, etc. on different levels (state, land, city). More: http://www.greenandhealthyhomes.org/what-green-healthy-home

- **Warm Up New Zealand:** In November 2017 New Zealand's parliament passed the Healthy Homes Guarantee Act 2017[3]. With this legislation New Zealand's government may specify a healthy home standard, which encompasses, inter alia, provisions for indoor temperatures that must be capable of being achieved and standards for heating, insulation, ventilation and others. Landlords have to comply with this standard. To further the goals of this legislation, the Energy Efficiency and Conservation Agency (EECA) has established "Warm Up New Zealand". This program provides grants of 50 % of the costs of insulation[4]. There are two cases in which building owners may be eligible for these grants: First, low-income owner-occupiers who qualify for a Community Services Card and landlords whose tenants qualify for a Community Services Card. Second, building owners or tenants whose income is just above the Community Services Card level but who have high health needs related to cold and/or damp housing. Also eligible for funding are building owners with a referral from the Ministry of Health's Healthy Home programme. Though being administered by an organisation responsible for energy efficiency, Warm Up New Zealand is an example of a program that puts other impacts of energy efficiency than energy savings in the foreground – primarily its health benefits.

The following three examples demonstrate how non-energy departments, ministries or organisations provide energy efficiency policies for multiple benefits reasons.

- **Warmth and Wellbeing[5]:** Warmth and Wellbeing is a pilot scheme currently (2018) being tested in parts of Dublin, Ireland. The program is a joint initiative by the Department of Communications, Climate Action and Environment (DCCAE) and the Department of Health and the Health Services Executive (HSE). The scheme is administered by the Sustainable Energy Authority of Ireland (SEAI). For being eligible for a grant of the Warmth and Wellbeing scheme, one household member younger than 12 or 55 and older has to be diagnosed with a chronic respiratory disease and the household must receive the fuel allowance (payment helping low-income households with energy costs). If a household qualifies for a grant, the SEAI will initiate energy efficiency improvements of the home at no cost to the owner or tenant. These measures may include insulation, ventilation, new windows and doors as well as a new heating system. The Warmth and Wellbeing scheme is part of the **Strategy to combat energy poverty 2016-2019[6].** This strategy is also interesting to the COMBI project for another reason. It contains a whole section dedicated to governance. The strategy acknowledges that energy poverty is a cross-government issue concerning many departments. With the strategy, the responsibility for coordinating Ireland's policy on energy poverty has been assigned to the Cabinet Committee on Social Policy and Public Service Reform. The Cabinet Committee works as a forum to bring ministers from various departments together. Every department involved with energy poverty (DCCAE, Department of Employment Affairs and Social Protection, Department of Rural and Community Development among others) has to report annually on its measures and

3 http://www.legislation.govt.nz/act/public/2017/0046/25.0/whole.html
4 https://www.energywise.govt.nz/funding-and-support/funding-for-insulation/
5 https://www.seai.ie/grants/home-grants/warmth-and-wellbeing/
6 https://www.dccae.gov.ie/documents/A%20Strategy%20to%20Combat%20Energy%20Poverty.pdf

progress at combating energy poverty. These reports form the basis for discussion and coordination of further activities. In light of the multiple impacts of energy efficiency, having a committee coordinating actions among departments responsible for one of the various sectors where energy efficiency might have impacts seems an appropriate approach and could help to find new funds.

- **Low Income Home Energy Program (LIHEAP):** LIHEAP is a program with a budget of 3.39 billion $ administered by the United States Department of Health & Human Services[7]. The biggest share of this budget is used to help low income households pay for their energy bills. Up to 15 % (25 % in case of a waiver) of the funds can also be used for what is called 'weatherization assistance' in the USA. In the fiscal year 2014, forty-two states chose to allocate more than 300 million $ for this purpose[8]. The LIHEAP program is administered by the federal states. The provisions of the LIHEAP program as to which activities may be funded as weatherization assistance are rather general[9]. The measures must be low-cost, cost-effective and constitute weatherization or home repair measures. Among the activities supported by the federal states are energy audits, insulation, heating system modifications and repairs, roof repairs, CFL light bulbs and others. LIHEAP is an example for a policy by a department responsible for health and human service, which includes some funding for energy efficiency in a program to alleviate the effects of poverty.
- **GreenOn Industries:** GreenOn Industries is a program run by the Ontario Centre of Excellence (OCE). The OCE is a non-profit organisation aiming to facilitate the development of Ontario's economy[10]. One of its main tasks is to bring research organisations and industry together to help commercialise new products originating from research and thereby creating new businesses, products and jobs. The GreenOn program targets large industrial emitters and provides funding for measures that deploy new technology (e.g. net zero buildings) and enable a significant reduction of greenhouse gas emissions[11]. While a measurable and deep greenhouse gas emission reduction is among the stated objectives of the program, another important goal is to increase industrial competitiveness. Therefore the case of the OCE's GreenOn Industries program can be seen as an example for an organisation with a mission that is not energy efficiency or climate protection funding such investments with another impact in mind. Funds for the GreenOn Industries program originate from the auction of emission allowances within Ontario's emission trading system.

1.4 Contribution of the COMBI project

Following the momentum of the 2014 IEA book on multiple benefits and the interest raised at European level of policy making, the COMBI research team identified the knowledge gap of having multiple impacts of energy efficiency quantified in one common framework rather than disperse and non-comparable studies on individual impacts.

---

7 https://liheapch.acf.hhs.gov/pubs/LCIssueBriefs/FinalLIHEAPPrimer.pdf

8 https://www.acf.hhs.gov/sites/default/files/ocs/fy14_liheap_rtc_final.pdf

9 https://liheapch.acf.hhs.gov/sites/default/files/webfiles/docs/LIHEAP_Weatherization_Report.pdf

10 http://www.oce-ontario.org/about-us

11 http://www.oce-ontario.org/programs/strategic-initiatives/greenonindustries/large-scale-technology-deployment-and-facility-modernization/

COMBI therefore added to the knowledge base on multiple impacts:

- In-depth literature screenings on multiple impacts, methods and outcomes
- Development and application of one common scenario basis (COMBI baseline and efficiency scenario) for the quantification of all impacts[12]
- Development and application of state-of-play methodologies for impact quantification and monetization
- Quantification and monetization of 32 impacts for 21 energy efficiency improvement actions for all 28 EU Member States
- Development of synthesis methodology for separate and joint consideration of impacts
- Development of a visual online tool for easy and open access to COMBI results

1.5 Which evaluation perspective?

For any evaluation of multiple impacts, the perspective of the assessment needs to be defined, i.e., from which stakeholder perspective the analysis is undertaken. Theoretically, many different perspectives of analyses or "cost tests" (the usual US term) are available. For understanding investment decisions, the individual investor/end-user perspective is most important. The aim of COMBI was primarily to inform policymakers and analyse energy efficiency from an overarching societal perspective. Therefore, the "societal evaluation perspective", analysing all impacts from an overall societal view is taken here.

Details on the different perspectives and the selection within the COMBI project are outlined in detail in the dedicated D2.7 Quantification report and D2.4 Synthesis report.

2 The COMBI approach and methods

COMBI provides estimates of the major multiple impacts in the year 2030 that result from energy efficiency investments that are additional to a reference scenario. The reference scenario considers all existing energy efficiency policies. Impacts are quantified by EU member state and by single energy efficiency improvement (EEI) action. Therefore, detailed input data on energy savings and investment costs were necessary: COMBI uses detailed stock models to this end. Outputs from this served as the common basis for impact quantifications. Finally, impacts were gathered in a common database for the online tool. This section outlines the COMBI approach and links to further information.

2.1 COMBI energy efficiency improvement actions and scenarios

COMBI energy efficiency improvement actions

COMBI covers energy efficiency improvement (EEI) actions that sum up to a scenario similar to the EUCO+33 to EUCO+35 EU scenario (scenarios are not directly comparable due to different methodologies, more details below). For each sector of buildings, transport and industry, technological (and some behavioural) energy improvement options have been grouped to form 21 EEI actions. Table 1 provides an overview.

Selection process and description of actions, see D2.3

Resulting scenarios and assumptions, see D2.3 Annex

12 The original plan of streamlining COMBI quantifications with official EUCO/PRIMES scenarios unfortunately was not possible due to repeated delays of official scenario publication as well as lack of input and output detail that was necessary for COMBI quantifications.

Table 1: List of selected end-use technical energy efficiency improvement actions for the COMBI project

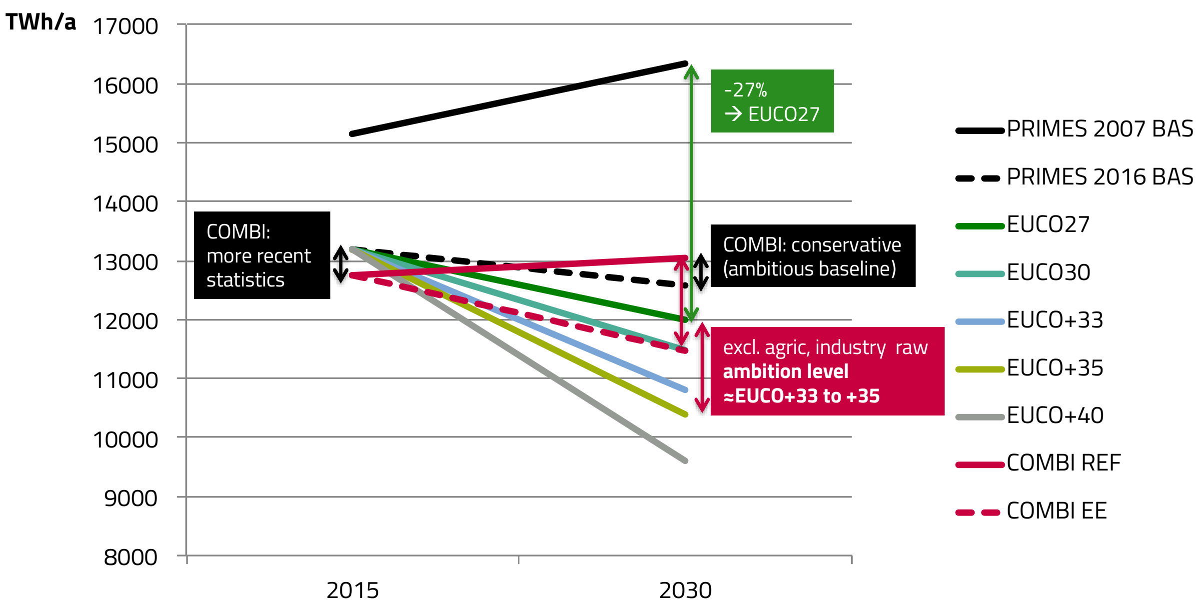
#	End-use energy efficiency action – improving energy efficiency in or through:
Action 1	residential refurbishment of the building shell + space heating + ventilation + space cooling (air-conditioning)
Action 2	residential new dwellings
Action 3	residential lighting (all dwellings);
Action 4	residential cold appliances (all dwellings);
Action 5	non-residential refurbishment of building shell + space heating + ventilation + space cooling (air-conditioning)
Action 6	non-residential new buildings
Action 7	non-residential lighting (all buildings)
Action 8	non-residential product cooling (all buildings)
Action 9	passenger transport – modal shift
Action 10	passenger transport – motorized two-wheelers
Action 11	passenger transport – cars
Action 12	passenger transport – public road/buses
Action 13	freight transport – modal shift
Action 14	freight transport – light duty trucks (LDT)
Action 15	freight transport – heavy duty trucks (HDT)
Action 16	industry (7 sectors) - high temperature process heating
Action 17	industry (7 sectors) - low and medium temperature process heating
Action 18	industry (7 sectors) – process cooling
Action 19	industry (7 sectors) – specific process electricity
Action 20	industry (7 sectors) – motor drives
Action 21	industry (7 sectors) – HVAC in industrial buildings

COMBI scenarios

The COMBI input data modelling exercise produced a baseline scenario (based on existing EU legislation) and an efficiency scenario (based on more ambitious assumptions on technology implementation following more ambitious policies).

The difference between the baseline and efficiency scenario is used as input data (i.e. additional energy savings and investment costs) for quantifying multiple impacts. These results were transferred to the other COMBI partners for application in their respective models. Also, only additional multiple impacts are quantified. This means, **COMBI quantifies the additional multiple impacts of more ambitious policy action**. One goal of COMBI scenario modelling was to provide a bottom-up foundation of the scenarios modelled for the European Commission's EED Impact Assessment and its annexes (based on PRIMES). Details on different modelling techniques and approaches are elaborated in the report D2.7. The ambition (amount of energy savings vs. the reference scenario of around 8%) of the COMBI EE-scenario is between the EU 33% and 35%-target (EUCO+33 to EUCO+35 EU scenario).

Figure 2: Energy efficiency scenarios



For details on scenario comparion and data summary see explanatory slides

Selection process and description of actions, see D2.3

Resulting scenarios and assumptions, see D2.3 Annex

2.2 Methods for multiple impact analysis

The COMBI project quantifies 32[13] different multiple impacts (MI) of energy efficiency improvement (EEI) actions, which require different type of assessment approaches (methodologies).

Table 2 summarises the quantification methodologies of the different work packages. The models are always used for quantifications in the year 2015 and 2030 and the avoided extent of the respective impact due to accelerated energy efficiency interventions (COMBI efficiency scenario resulting from 21 energy efficiency improvement actions). The overview on individual methodologies is available in greater detail in the synthesis report (D2.4). Details on the respective methodologies for the different impact quantifications by each Work Package in the final quantification reports on the COMBI website.

13 1 Energy- and 31 (non-energy) multiple impacts.

Table 2: Summary of quantification methodologies (impacts modelled are changes in impact indicators)

Work packages ↗ to further information	**Impact indicators**	**Description of the quantification methodology**
WP3: Air pollution ↗ D3.4	Human health	Reduction in premature mortality due to the exposure of different outdoor pollutants by using GAINS model
	Eco-systems: acidification	Total ecosystem area spared from acidification by using GAINS model
	Eco-systems: eutrophication	Total ecosystem area spared from eutrophication by using GAINS model
	Air pollution: Emissions (impact mid-points)	Reduction in outdoor air pollutants emission from fuel combustion and transportation by using GAINS model
WP4: Resources ↗ D4.4	Material Footprint (total of fossil fuels, minerals, metal ores, biotic materials, unused extraction)	The Material Footprint is the sum of extracted abiotic (fossil fuels, metal ores, minerals) and biotic raw materials from nature, including the extraction of economic unused materials. Change quantified using Material Flow Accounting.
	Fossil fuels	Accounting (through Material Flow Accounting) of all raw materials from nature, that can be classified as fossil fuels and are put to an economic use.
	Minerals	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as minerals and are put to an economic use.
	Metal ores	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as metal ores and are put to an economic use.
	Biotic raw materials	Accounting (Material Flow Accounting) of all raw materials from nature, that can be classified as biotic raw materials and are put to an economic use.
	Unused extraction	Accounting of materials that are extracted from nature (Material Flow Accounting), that are not translocated from site or put to a direct economic use. This includes overburden and by-catch as well as waste on site.
	Direct carbon emissions	Direct carbon emissions are based on emission factors for different fuel types found in the IPCC reports. Values are listed in CO_2 equivalents per unit of energy.
	Carbon Footprint (GWP, lifecycle missions incl. direct emissions)	Life-cycle Assessment of characterised greenhouse gases and their global warming potential in 100 years (GWP 100a). Characterisation factors are based on the IPCC reports.
WP5: Social welfare ↗ D5.4 (energy poverty) ↗ D5.4a (productivity)	Excess winter mortality attributable to inadequate housing	Reduction in premature mortality due to inadequate heating and cooling, quantified by dedicated modelling.
	Excess winter morbidity attributable to inadequate housing	Reduction in morbidity due to inadequate heating and cooling, quantified by dedicated modelling.
	Indoor dampness/asthma	Reduction in asthma incidence due to dampness in the building, quantified by dedicated modelling.
	Active days (impact through health-asthma, allergy, cardiovascular disease, cold and flu and traffic time saved)	Indoor exposure dose-response model is used to calculate the indoor exposure-related active days and basic reduction method is used to calculate congestion-related active days, quantified by dedicated modelling.
	Workforce performance	Basic performance improvement equation is used to calculate workforce performance, quantified by dedicated modelling.

Work packages to further information	Impact indicators	Description of the quantification methodology
WP6: Macro-Economic impacts D6.4	Temporary (business-cycle) aggregate demand (potential GDP increase)	Input/output analysis and fiscal multiplier analysis based on additional investment and energy (cost) savings
	Temporary (business-cycle) employment	Input/output analysis and fiscal multiplier analysis
	Temporary (business-cycle) public budget effects	Input/output analysis, fiscal multiplier analysis and budgetary semi-elasticities
	Fossil fuel price effects	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	Changes to marginal abatement costs	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	Terms of Trade effect	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
	Sectoral shifts	General equilibrium modelling (Copenhagen Economics Global Climate and Energy Model - CECEM)
WP7: Energy security D7.4	Energy intensity	Final energy demand reduced by COMBI actions (WP2) divided by GDP
	Import dependency	COMBI Energy balance model. Main input is final energy demand reduced by COMBI actions (WP2). Relevant output is change in net imports. Net imports of fuels multiplied by their respective energy prices
	Aggregated energy security	COMBI Energy balance model. Relevant output is net imports. Allocation model to determine country of origin of imports. Use of risk indicators to assess political risks.
	Avoided electric power generation & investment costs	COMBI Energy balance model. Power sector model to determine mix of power plant and cogeneration plant technologies and capacities. Relevant generation output is net power output. Avoided investment costs: avoided power capacity multiplied by specific capital costs per technology.
	Derated reserve capacity rate	COMBI Energy balance model and power sector model. Model to determine peak loads and required reserve capacities based on annual load duration curves.

Source: Own elaboration (data provided by COMBI partners)

2.3 Impact synthesis

The target of COMBI is to bring all quantified multiple impacts together in one unified database and to perform a cost-benefit analysis (CBA) that includes as many multiple impacts as possible. The first pre-condition for multiple impacts to enter any CBA is that they can be brought to a common unit, i.e. that they can be monetized. The second precondition is to include only impacts, where any danger of double-counting can be definitely ruled out. To this end, COMBI developed a systematic way of looking at impacts, leading to the exclusion of many quantified and monetized impacts from CBA although they would at least *partially* be additive.

Figure 3 shows the complex pathways of impacts quantified in COMBI. All possible interaction effects were discussed in detail and either ruled out in quantification methodologies or accounted for. Where they could not be entirely excluded, the decision was not to allow the respective impacts to enter CBA. The D2.7 report outlines and the D2.4 report describes the proceeding in detail. Table 4 in the Annex lists impact end-points with their possible inclusion (✓) or exclusion (✗) to the COMBI CBA and gives a brief reasoning for their in-/exclusion.

Only a very limited number of COMBI-monetized actions could be included into the CBA for which double-counting could be ruled out completely. For a detailed table with reasoning per impact, see Table 4 in the Annex. The net result of the COMBI CBA should thus be regarded as a conservative estimate of the cost-effectiveness from a societal perspective, as

- several impacts that do certainly exist could not be monetized (or even physically quantified);
- where there was even danger of *partial* double-counting we excluded impacts;
- quantification methods mostly are conservative (e.g. not quantifying all impact pathways, reference scenario is ambitious, i.e. fully complying with current policies).

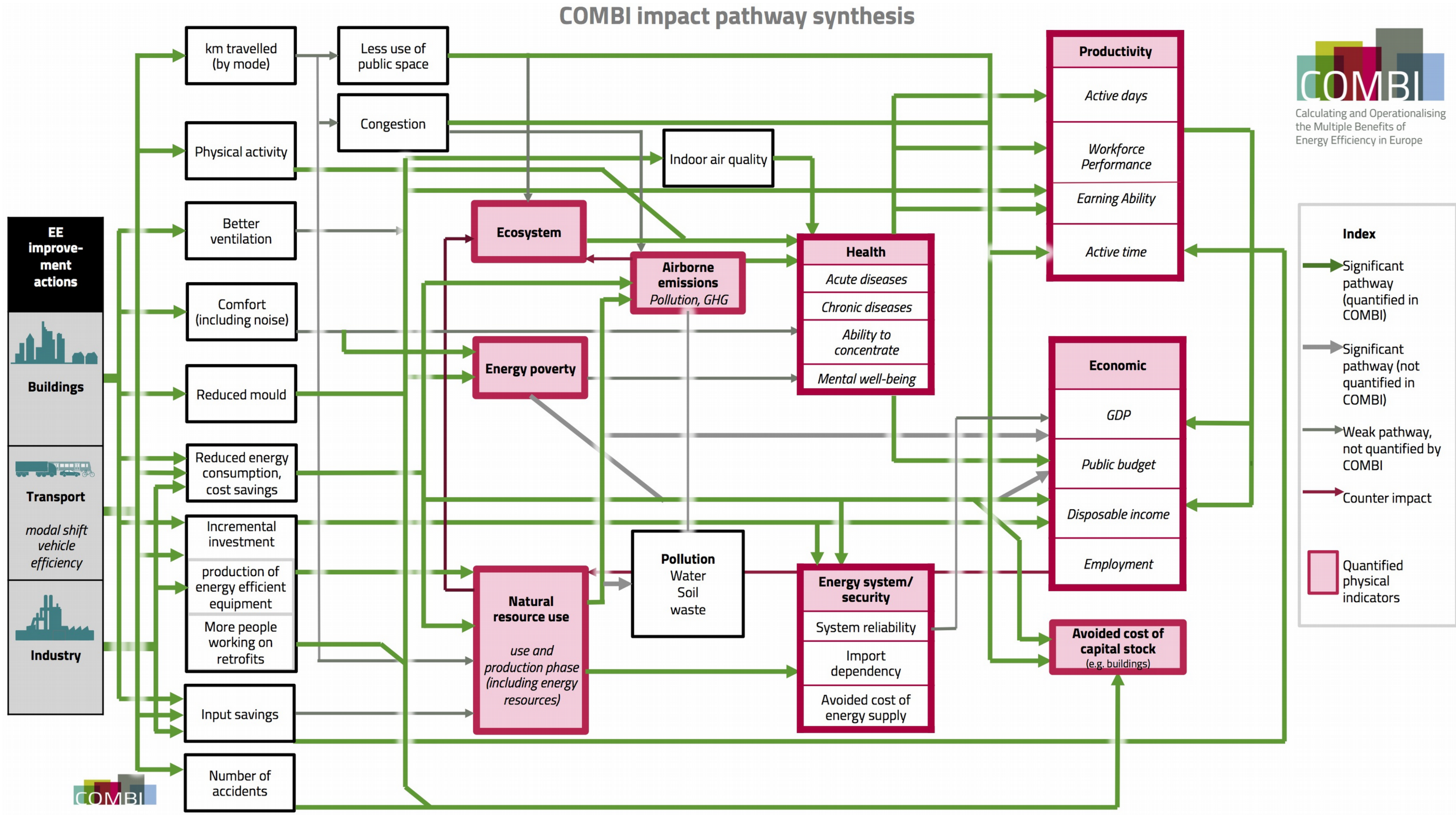


Figure 3: Impact pathway map incorporating all the impact category

Source: Own elaboration

2.4 Cost-Benefit Analysis

COMBI allows for the calculation of a variety of cost-benefit indicators:

- Life-Time net present value
- Annualised net present value
- Levelised cost of energy saved and of GHG emissions saved
- Cost-benefit and benefit-cost ratios (CBR/BCR)
- Marginal cost curves (MCC)

The quantification report D2.7 outlines the approach of the CBA. Furthermore the mathematical formulae for the calculation of each indicator are explained in detail in the D8.1 Tool documentation.

2.5 Methodological caveats and sensitivity analysis

COMBI results depend, as any forward-looking scenario analysis, on many assumptions. These have to be kept in mind when communicating and working with the project results. In addition, there are other caveats and open issues:

- Missing data and data limitations
- Model limitations
- Linking models and modelling interdependencies

Remarks on uncertainties and further research needs

As any forward-looking research that involves modelling, the various models applied for multiple impact estimation in the COMBI project have to draw on numerous assumptions and external data projections all of which are subject to uncertainty. Researchers intended to provide maximum transparency on the caveats (for a summary, see D2.7) and uncertainties through explanations in the reports. However, as all modelling results, COMBI estimations are no projections but estimates, based on best available methods. A number of issues need to be highlighted:

- COMBI is based on the assumption that additional EEI actions (beyond a current policies scenario) are implemented. In order to happen, this will need additional ambitious and dedicated policy measures that really drive the implementation of these actions. Such policies were not subject of the project.
- Some impacts will only materialise if targeted policies are implemented, such as targeted energy poverty policies that drive building renovations primarily for the people living in energy poverty (e.g. through addressing the social housing sector, split incentives dilemma or financing issues).
- Some impacts will only materialise if certain framework conditions are met, e.g. short-term macro-economic effects only will be realised in a situation of free economic capacities that can absorb the additional demand stimulus turn it into additional turnover. As projections of this condition until 2030 is not possible, we can only estimate *potential* effects.
- Every single impact indicator shows differences between countries and EEI actions. This comes from different country contexts COMBI tried to map as far as possible. But further research in a country is needed for better national foundation of dedicated policies. How-

ever, COMBI results may indicate that priorities on which impacts matter most vary between countries – there is no one size fits all EU focus.
- While multiple impacts may show large effects in physical units, monetised values may seem small. This points to contested monetization methodologies and ethical debates around the valuation of human health and lives. This discussion is not solved and may lead to different conclusions at national levels if different approaches are pursued.

Sensitivity analysis

COMBI results are generally point estimates resulting from complex modelling exercises to quantify the impacts for the two scenarios, the reference and efficiency scenario, or sometimes directly for their difference. By nature, such models include numerous assumptions, most of which are laid down in the respective quantification reports of the Work Packages 2–7 (D3.4–D7.4).

In general, most impacts are non-linear with respect to changes in input parameters (energy savings and investments). This makes intra- or extrapolation of results difficult if not impossible. It would require much more intensive modelling work on sensitivities to identify input-impact curves than what was possible in the COMBI project. Some sensitivities were studied in the respective D3.4–D7.4 quantification reports. In addition to these, COMBI also included two options for users of the online tool to directly test CBA results for sensitivity on two variables, in the expert mode:

- Energy price scenarios (deviating ±10% from the COMBI forecast)
- Discount rates directly entering the CBA calculation formula (COMBI standard rate at 3%, option for user to apply different rates from 0–10%)

For details on caveats and sensitivity analysis, see report D2.7.

Review of project results

All COMBI reports and methodologies have undergone a multiple-step review process: (1) internal (cross-partner and coordinator) reviews, (2) assessment and review by representatives from the COMBI scientific advisory board and (3) in many cases presentations and discussions on scientific conferences and with other external experts, and (4) a number of publications have already undergone peer-review processes of journals. Finally, the project was reviewed by two independent experts contracted by the granting authority (EASME) and their recommendations and feedback have been incorporated.

3 Insights on specific impacts

COMBI quantified all impacts by EU28 member state and on a EU28 level, and by each of the 21 EEI actions, i.e. a 28x21 matrix of impacts. The main input data used for impact quantifications includes additional annual energy savings, the corresponding energy cost savings, and additional investment costs (in annualised form) . Graphs below provide an overview on this data, respective tables are included in the annex of the quantification report D2.7. Full details of data can be retrieved from https://combi-project.eu/charts/

In the tool, mouse-over tooltips additionally give detailed values and a data export function allows downloading all data tables.

[D8.1 Detailed manual](#) on how to use the tool and documentation of technical tool infrastructure is available from the download section of the website and directly in the tool

Tool https://combi-project.eu/charts/

3.1 Input data: additional investment, energy and energy cost savings

The implementation of all [21 EEI actions](#) at the level of ambition assumed for the COMBI EE-scenario would lead to additional annual final energy savings in 2030 compared to the reference scenario illustrated in Figure 4 for the respective EEI actions. They **sum up to 1647 TWh/year or 142 Mtoe/year in 2030**. It should however be noted that different forms of final energy, such as electricity and fuels, cannot directly be compared to each other.

Figure 4: Additional final energy savings (all fuels, total EU28) in TWh/year in 2030 by EEI action

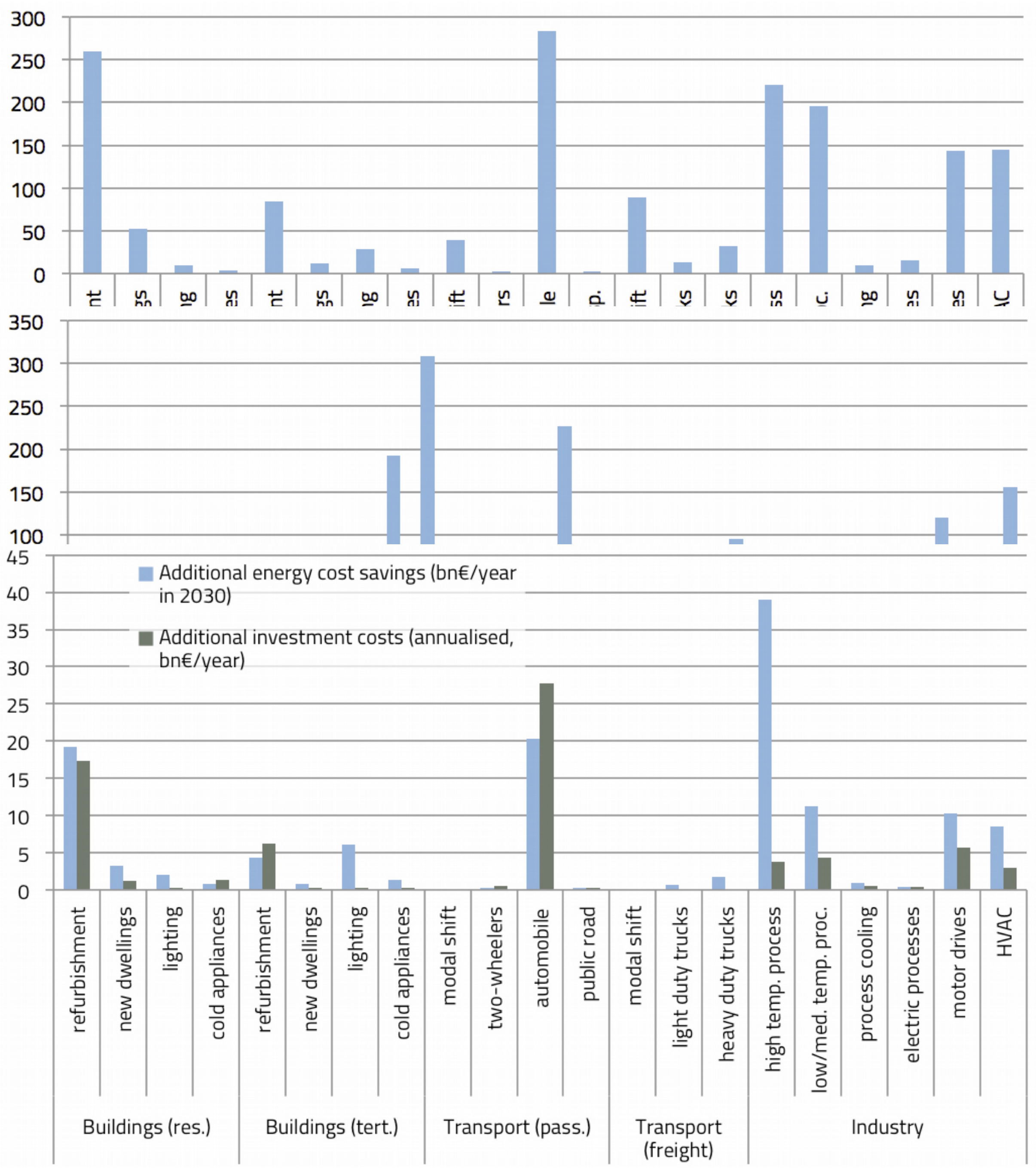
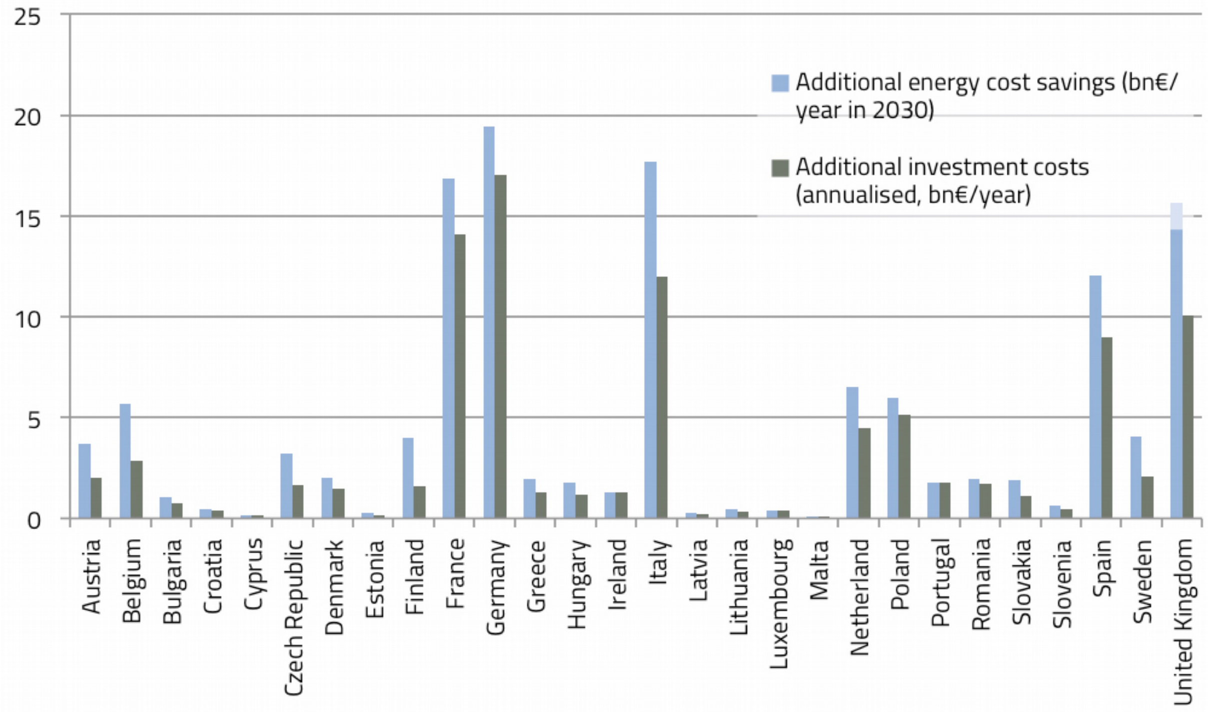


Figure 7: Additional energy cost savings and (annualised) additional investment costs in bn€/year by EU28 member state (societal perspective)



[View graph in COMBI tool (CBA graph)](#)

These figures show the energy impacts – energy savings and energy cost savings – of additional energy efficiency actions for the COMBI efficiency scenario. Thus for most EEI actions and for all EU Member States, the energy cost savings are already higher compared to the investment costs. **Total energy cost savings** from the COMBI efficiency scenario[14] would be **128 bn€/year in 2030**, outweighing the **annualised investments of 73 bn€/year**. Results from COMBI quantifications show that further non-energy impacts add significant benefits, including economic benefits. These "multiple impacts" are outlined in the following chapters.

Multiple impacts: results from COMBI quantifications

COMBI quantified all impacts by EU28 member state and 21 EEI actions. In total impacts cover energy savings, investment costs plus 30 additional impacts, for 17 of which it was possible to also monetise them. However, there are double-counting issues for a number of impacts, therefore only 11 were included into the CBA. For more details on the CBA see chapter 4.2 and especially the D2.4 synthesis methodology and D8.1 online tool report.

Due to the resulting amount of data and possible graphing combinations, only selected results are shown in this 2.7 report. All impacts quantified by COMBI are available from the COMBI online tool (https://combi-project.eu/tool/)

- by country
- by EEI action
- physical, monetary (where possible), in CBA (where eligible)

The following section presents snapshots of the data and graphs available from the tool.

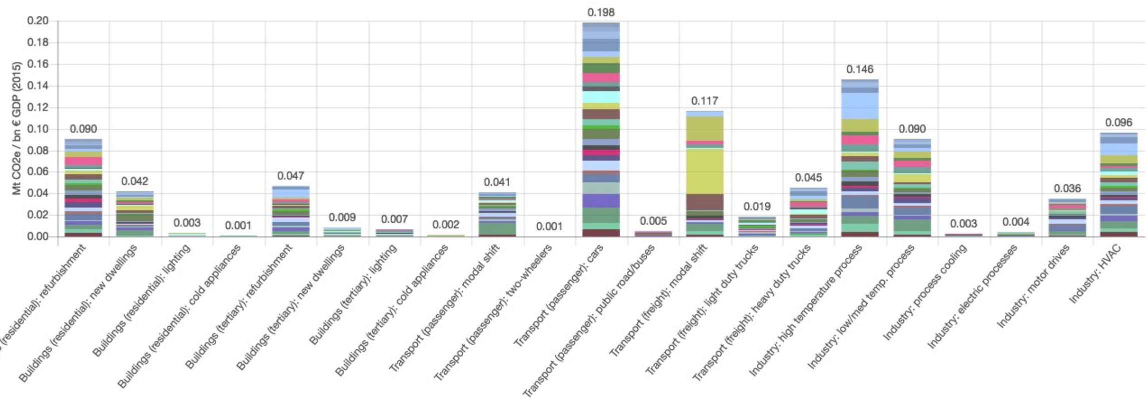
14 all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of outdated investment costs.

3.2 Climate impacts: Mitigation of 360–500 Mt CO_{2eq}/year

COMBI quantifies two impacts on the climate: savings of direct GHG emissions in Europe (combustion of fossil fuels from final energy use), and savings in the global carbon footprint including upstream emissions from energy supply systems and infrastructures. For transport and lighting actions, also emissions from the production phase of energy efficiency products (vehicles, lighting systems) are included.

Total avoided direct emissions in the EU by COMBI EEI actions sum up to 362 Mt annually. Including indirect upstream emissions (not restricted to the EU), the avoided EU carbon footprint amounts to 509 Mt/a.

Figure 8: Avoided direct GHG emissions (per GDP, in 2030) from fuel combustion in Mt CO_{2eq}/bn € of 2015 GDP in the EU28



[View graph in COMBI tool](#)

[View graph in COMBI tool](#) **(carbon footprint incl. indirect emissions)**

Key results

- high impacts from transport and industry sector
- especially high impacts in Eastern European (EEU) countries (view graph in COMBI tool)

3.3 Macro-economy: up to 1% of GDP, 2.3mn job-years and lower fossil fuel prices

Macro-economic impacts are quantified using two modelling approaches: input-output modelling for short-term (business cycle) effects and CGE modelling for long-term/structural effects. As also seen in other modelling (e.g. EU-COM impact assessment of EED), these models give a range of possible outcomes.

In the short run, the positive macro-economic stimulus is substantial due to the size of the investments resulting from COMBI actions; looking at the year 2030, we estimate 0.9 per cent of EU's GDP and a positive effect on the labour market of about 2.3 mn job-years, if EEI actions are implemented as assumed over time. This economic stimulus can be a positive contribution in countries with idle resources that can support further growth (negative output gap, situation of economic downturn). In 2018, about half of the EU28 Member States are expected to have a negative output gap. However, even countries with a positive output gap (indicating full use of existing production capacities) sometimes display high unemployment figures, in which e.g. capacity building for human capital could significantly increase the production capacities for energy efficiency investment, and hence the potential in the economy to absorb the demand stimulus for growth and employment.

Public budget effects are estimated by applying budgetary semi-elasticities to additional aggregate demand. The total effect (additional tax revenue) amounts to up to €85 bn annually in 2030 (under the condition that investments come from the private sector). This would give Member States ample room for investing a part of this expected surplus in energy efficiency policies, in order to make the surplus a reality.

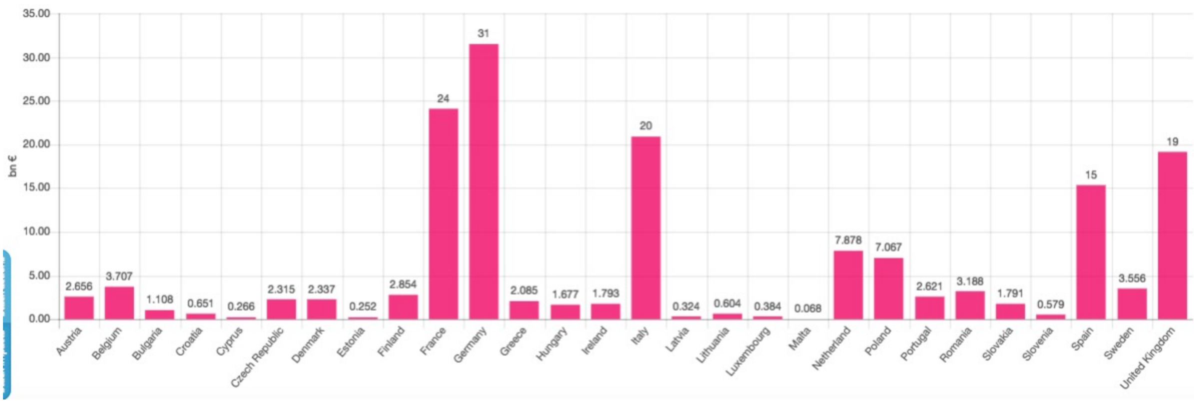
In the long run, CGE (Computable General Equilibrium) modelling does not show significant impacts on employment and slightly negative impacts on GDP. However, energy efficiency will lead to a reduction in CO_{2eq} emissions and significantly lowered carbon allowance and fossil fuel prices, which, as all EU countries are net fossil fuel importers, will improve their terms of trade.

This section presents only short-run impacts, long-run impacts are included in the D6.4 quantification report: D6.4 quantification report

GDP and employment impacts

The GDP effects vary between member states. Figure 9 highlights which countries would see which short-term increase in GDP. Not surprisingly, large countries show large impacts. Therefore, any impact quantifications can also be normalised to make more meaningful comparisons. The result shows that especially Eastern European Countries see larger GDP increases.

Figure 9: Short-term potential increase in GDP (bn€/year) by EU28 member state in 2030[15]



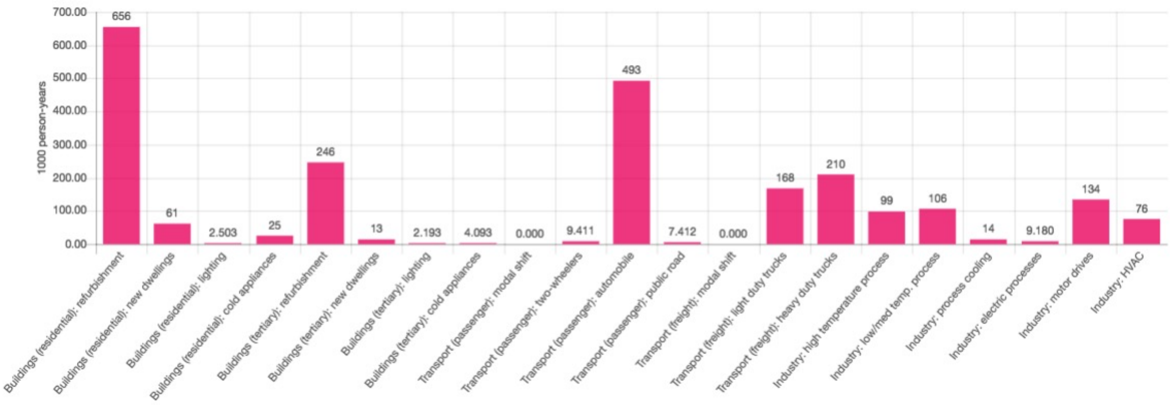
View graph in COMBI tool

View graph in COMBI tool, normalised by 2015 GDP (i.e. in % points)

View graph in COMBI tool (by EEI action)

15 Note: based on the assumption of an existing output gap in 2030.

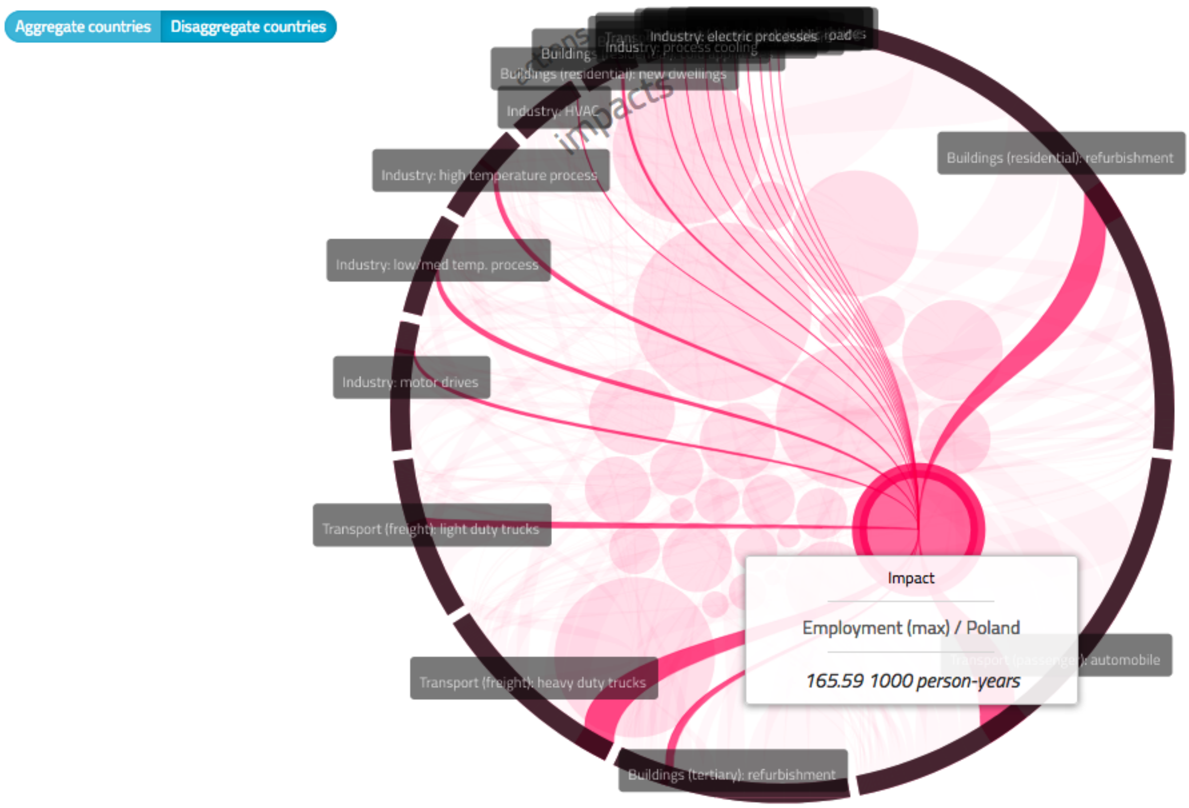
Figure 10: Direct (short-term) potential employment effect in 1000 person-years[16] by EEI action in 2030



[View graph in COMBI tool]

Figure 10 shows that the largest number of jobs may be created from EEI actions with high investment values and implemented in labour-intensive sectors: the buildings – both residential and tertiary – and the transport sector. In total, 2,343,000 person-years of employment could be created. For distribution between actions and countries see Figure 11 (can only be meaningfully viewed online with mouse-overs).

Figure 11: Halo graph of direct (short-term) potential employment effect[17] in 1000 person-years in 2030 for all EEI actions (ring) and EU28 member states (bubbles)

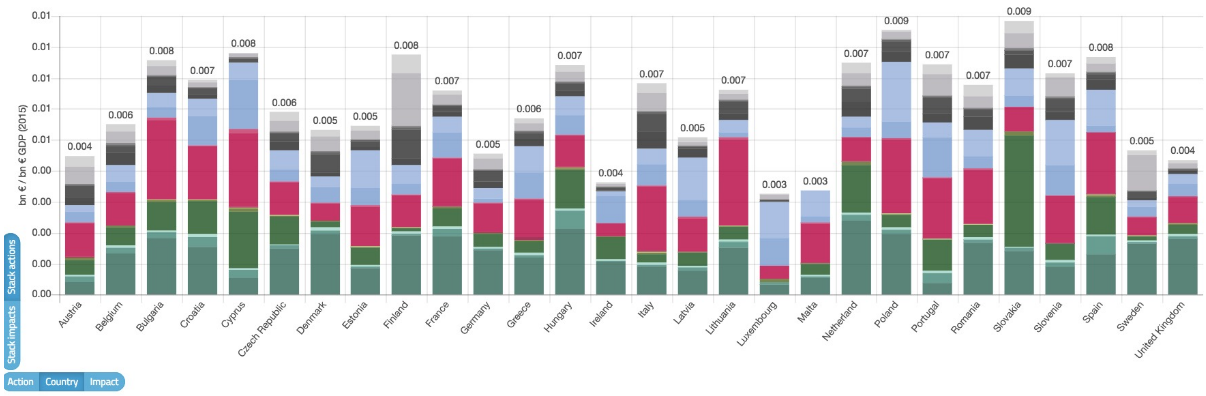


[View graph in COMBI tool – online version permits mouse-over information]

16 Note: based on the assumption of an existing output gap in 2030.
17 Note: based on the assumption of an existing output gap in 2030.

Public budget effects

Figure 12: Public budget effect[18] (in relation to 2015 GDP, e.g. 0.008 = 0.8%))



[View graph in COMBI tool]
[View graph in COMBI tool] **(absolute values in bn€ per country)**

Key results

- positive net public budget increase in all EU countries together of 85 bn€/yr
- public budget effects (in absolute terms) not surprisingly are highest in the larger EU countries France, Germany, Italy, Spain and the United Kingdom
- public budget effects expressed per GDP (as in Figure 12) are more evenly distributed among the EU28
- EEI actions with a marked effect are mainly from the transport and buildings sector (due to higher budgetary semi-elasticities), with some country-specific deviations

3.4 Air pollution

Air pollution is still the single largest environmental threat to human health in Europe. COMBI applied the GAINS model (Greenhouse Gas – Air Pollution Interactions and Synergies model from the IIASA institute) to quantify effects of accelerated energy efficiency improvements on air pollution.

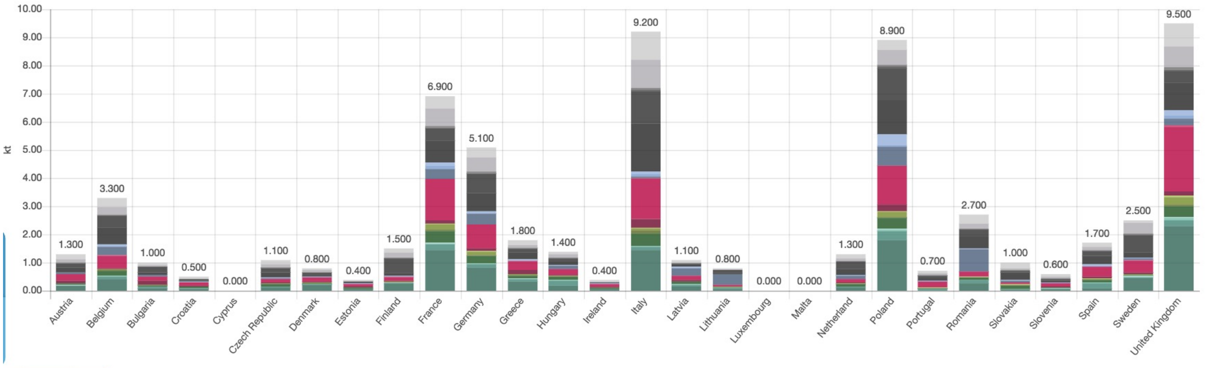
All air pollutants in COMBI, are measured in kilotonnes (kt). Note: the COMBI quantification was done for total energy savings per country and allocated to EEI actions by weights of energy savings. As air pollutants are not impact end-points, but mid-points leading to further health and ecosystem impacts, they are not presented in detail. For results on PM2.5, PM10, NOx, VOC and SOx emissions, please refer to the D2.7 report or the online tool. Below, only PM2.5 emission reductions by country are presented as an example.

For impacts resulting from air pollution on ecosystems and human health, refer to section 3.5.

More details and full quantification report

18 Note: based on the assumption of an existing output gap in 2030.

Figure 13: Avoided PM 2.5 emissions in EU-28 in 2030



[View graph in COMBI tool]

Key results

- Countries with especially high PM2.5 reductions are Italy, Poland and the UK, followed by the large countries France and Germany.
- In Italy, 9,200 kt of PM2.5 emissions could be avoided, half of the reductions originate from the industry sector. In other countries, avoided emissions are more evenly distributed between sectors.
- Further energy efficiency actions with major impact on PM2.5 reduction: buildings (residential) refurbishment and more efficient passenger transport (cars)
- "In monetary terms, the value of avoided mortality […] in 2030 would be 460 million EUR due to PM2.5 […] for the EU-28" (see report D3.4).

3.5 Health impacts from air pollution and energy poverty-related building conditions

Different health impact pathways have been analysed in COMBI: health impacts resulting from different air pollutants, from residential and tertiary building indoor conditions, affecting different types of health/sickness and even mortality (see reports D3.4, D5.4 and D5.4a). Accordingly, impacts are quantified in different units: mortality (number of premature deaths), years of life lost (YOLL) and disability-adjusted life-years (DALY), each according to a specific burden of disease following from certain pressures on health (see expert mode of the tool).

In the standard mode of the tool, all mortality-unit impacts are pre-aggregated as are all life-year related impacts (cf. Figure 16).

Health impacts from air pollution

Human health effects arise as a result of short and long-term exposures to various pollutants, and can take the form of respiratory or cardiovascular diseases, as well as negative prenatal and developmental outcomes. Although significant air quality improvements have been achieved in the last decades in Europe, air pollution is still the single largest environmental threat to human health, causing acute and chronic diseases.

Additional impacts (or co-benefits) to be achieved by an accelerated energy efficiency policy and its implementation in the EU-28 in 2030 year alone are:

- additional 10,805 premature deaths could be avoided due to reduced exposure to particulate matter (PM2.5)

- additional 442 deaths could be avoided due to reduced exposure to ground level ozone
- avoided life expectancy loss due to PM2.5 exposure for the surviving population in 2030: around 230,000 YOLLs
- additional 4.4 thousand km2 would de spared from acidification
- additional 13.3 thousand km2 would be spared from eutrophication
- In monetary terms, the value of avoidable mortality may amount to 460 million EUR due to PM2.5 and 46 million EUR due to ground level ozone in the year 2030 for the EU-28.
- The value of avoided life expectancy loss would stand at immense 26 billion EUR in 2030 for the EU-28
- monetary values of impacts have been calculated using Value Of a Life Year (VOLY) approach and can be considered as a conservative estimate as it does not include the costs associated with treating these health impairments and consequent lost productivity

Notes:

- as with all impacts, these are *additional* values, the difference between the two scenarios for the year 2030.
- the GAINS model only covers mortality effects (not morbidity effects). It can be expected, that morbidity is much more relevant for air pollution, therefore the GAINS-model results are an underestimation of the extent of true impacts.

Energy poverty-related health impacts

According to the European Union's Survey on Income and Living Conditions (EU SILC), 9.4% of European Union's population were unable to keep their homes adequately warm and 15.2% lived in residential housing characterized by a leaking roof, damp walls, floors or foundation, and rot in window frames or floors in 2015. COMBI quantified the energy poverty-related public health impacts in the year 2030 of accelerated building refurbishments between 2015 and 2030 – avoided excess cold weather deaths due to reduced indoor cold exposure and avoided/reduced asthma due to reduced indoor dampness exposure.

There is a mismatch between those who can afford energy efficiency retrofits and those who need them the most and would benefit from them the most (not only energy savings, but also improved health). Therefore, depending on scenarios of whether policies are targeted towards the socially vulnerable or not at all, the results show:

- 3,000–24,000 avoided premature deaths due to reduced indoor cold
- 2,700–22,300 avoided disability-adjusted life years (DALYs) caused by asthma morbidity due to reduced indoor dampness
- The associated economic value of avoided annual public health damage in 2030 ranges from 323 million EUR to 2.5 billion EUR for premature mortality due to indoor cold; and
- 338 million EUR to of 2.9 billion EUR due to asthma morbidity from indoor dampness.
- no assessment of morbidity effects possible with GAINS

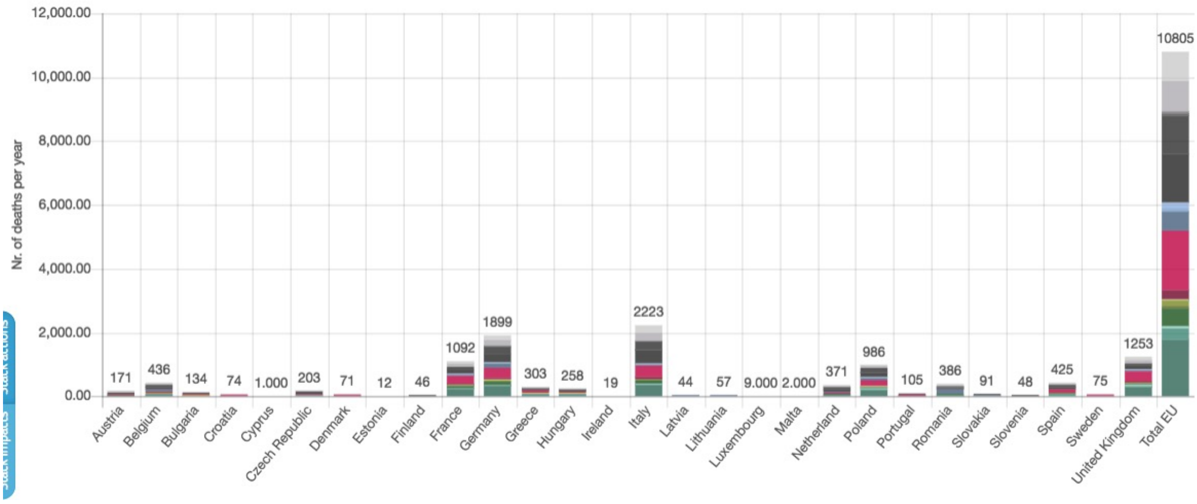
D3.4 quantification report on air pollution-related impacts

D5.4 quantification report on energy poverty-related impacts

Figure 14 shows that in case of the COMBI efficiency scenario, additional 10,805 premature deaths would be avoided in the year 2030 alone due to reduced exposure to PM2.5 in the EU-28 (cf. report D3.4).

A relatively large number of deaths is avoidable from energy poverty-related health issues due to building indoor conditions (excess cold weather deaths) that improve with the respective residential actions and have a strong impact of around 25,000 avoided deaths per year for the whole EU (in the case of a strong social policy that targets the energy poor specifically within all member states). Under a weak social policy, the number of avoided premature deaths in 2030 would stand at only around 3,500 (See D5.4 quantification report).

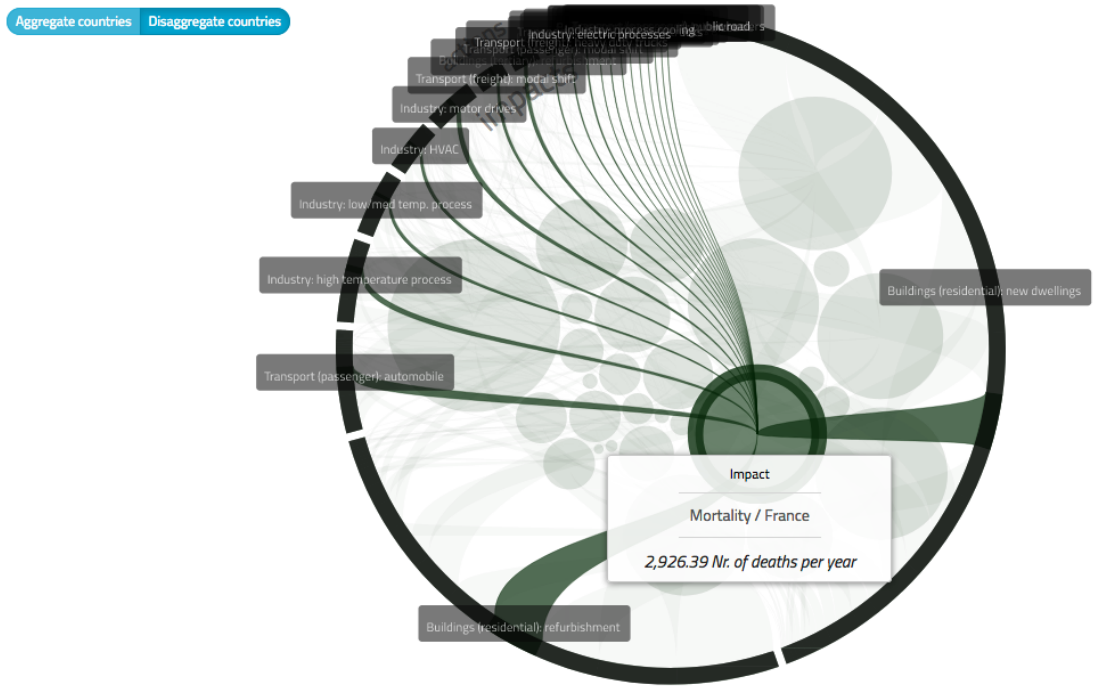
Figure 14: Number of avoided yearly premature deaths (in 2030) due to avoided PM2.5 exposure in the EU-28



View graph in COMBI tool (CBA graph)

Mortality figures for all (residential + other) actions also come from air pollution. For all actions, avoidable annual deaths amount to around 35,000. Most avoided premature mortality concentrates around the effects of residential housing refurbishment and new quality residential housing because premature mortality due to indoor cold concentrates in the residential building sector and the presented figures come from the strong social policy scenario. Avoided premature mortality due to air pollution spreads out across all energy efficiency improvement actions.

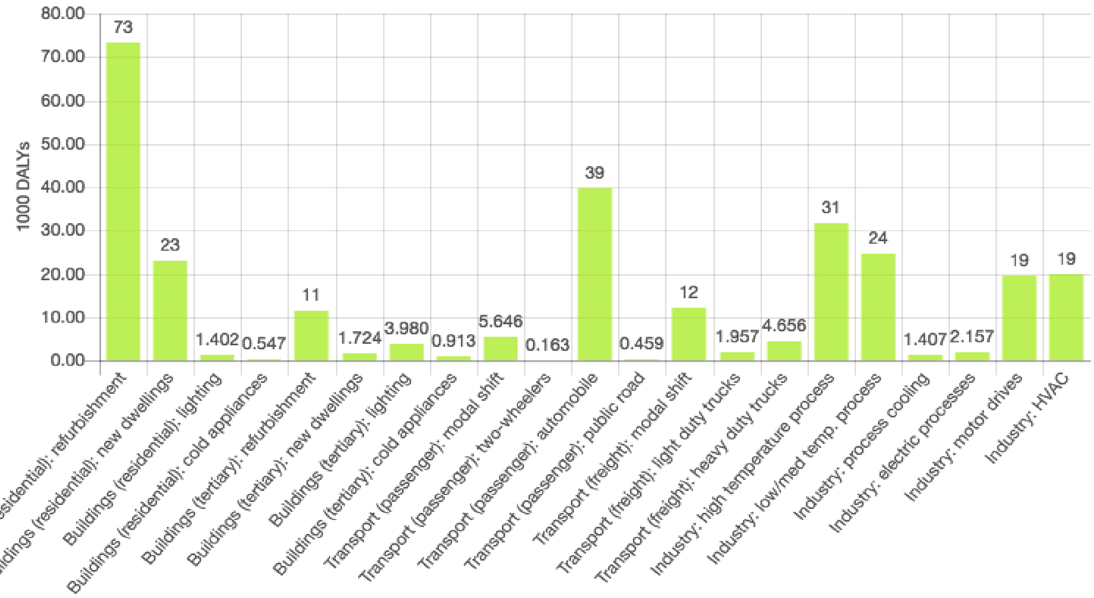
Figure 15: Halo graph of avoided mortality (nr. of deaths per year) due to lower levels of air pollution (ozone and PM2.5) and avoided excess winter mortality due to improved indoor conditions and lower health risks in 2030 by all COMBI EEI actions (ring) and EU28 member states (bubbles)



[View graph in COMBI tool – online version permits mouse-over information]

In a "halo" graph, e.g. PM2.5 mortality can be displayed by EU member states (bubbles) and EEI actions (ring) in the COMBI tool (see Figure 15). In addition to mortality due to PM2.5 exposure measured in years of life lost (YOLL) in the year 2030, also morbidity impacts to the surviving population are quantified in disability-adjusted life years (DALY). The aggregated figures from different impact chains (health from better building indoor conditions, from outdoor air pollution and polluted air infiltrating indoors) indicate that EEI actions with high savings of fossil fuels have a strong impact, most prominently building refurbishment and transport, but also industry actions. In addition to the building refurbishment impacts, there are strong impacts from improved indoor air quality. In total, the loss of 281,000 DALYs could be avoided.

Figure 16: Overall health impacts measured in gains of healthy life years (DALY) in 2030 from several causal chains (building refurbishment, indoor/outdoor air pollution)



View graph in COMBI tool (CBA graph)

3.6 Labour productivity: Shifting from non-refurbished to refurbished buildings can mean 4.5 additional annual work-days/person

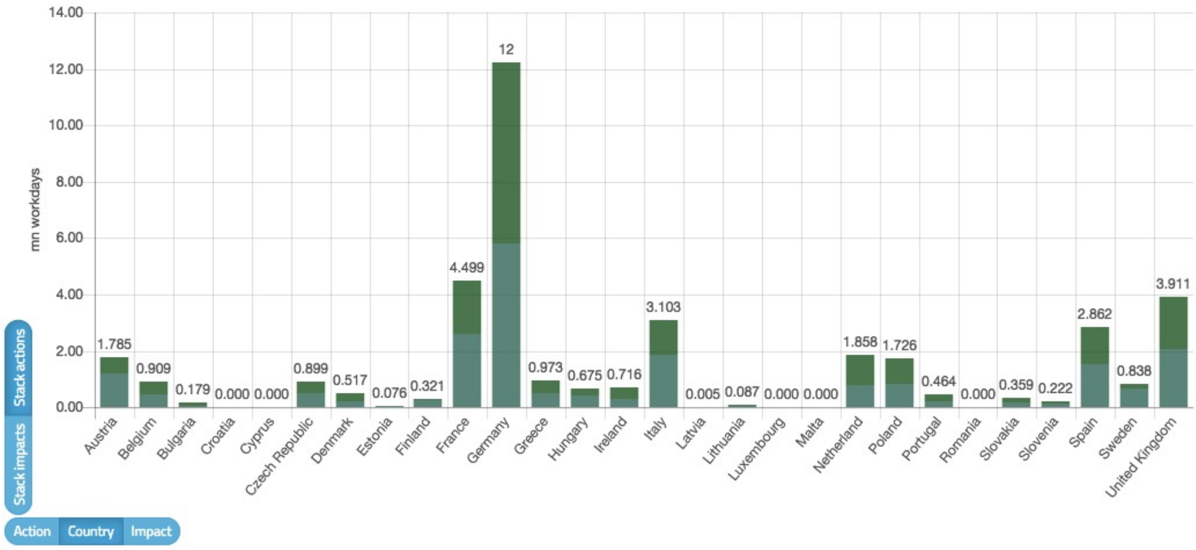
Human productivity following improved health conditions from building refurbishment and transport modal shift were estimated too. Several new metrics such as active days, workforce performance and earning ability are proposed to measure productivity. Accelerated EEI actions between 2015 and 2030 would bring the following additional benefits in the year 2030:

- on an average 4.5 active work days/person per annum can be gained if living in more deeply retrofitted buildings, passive houses, and nearly zero energy buildings.
- In addition, by improving the mental well-being, a European country can gain on average around 15.7 million euro/year per million population, and on an average 1961 healthy life years per annum can be gained by avoiding exposure to bad indoor air quality and conditions.

By opting for modal shift towards active transportation, on an average 1.6 hours/driver can be saved from traffic congestion in a year. The total amount of time savings from transport quantified by COMBI is however marginal compared to other productivity impacts.

More details and D5.4a quantification report

Figure 17: Gain in active days (mn workdays in 2030) by EU28 member states



View graph in COMBI tool (incl. colour legend)

3.7 Resource impacts: 850Mt annual savings of material resources

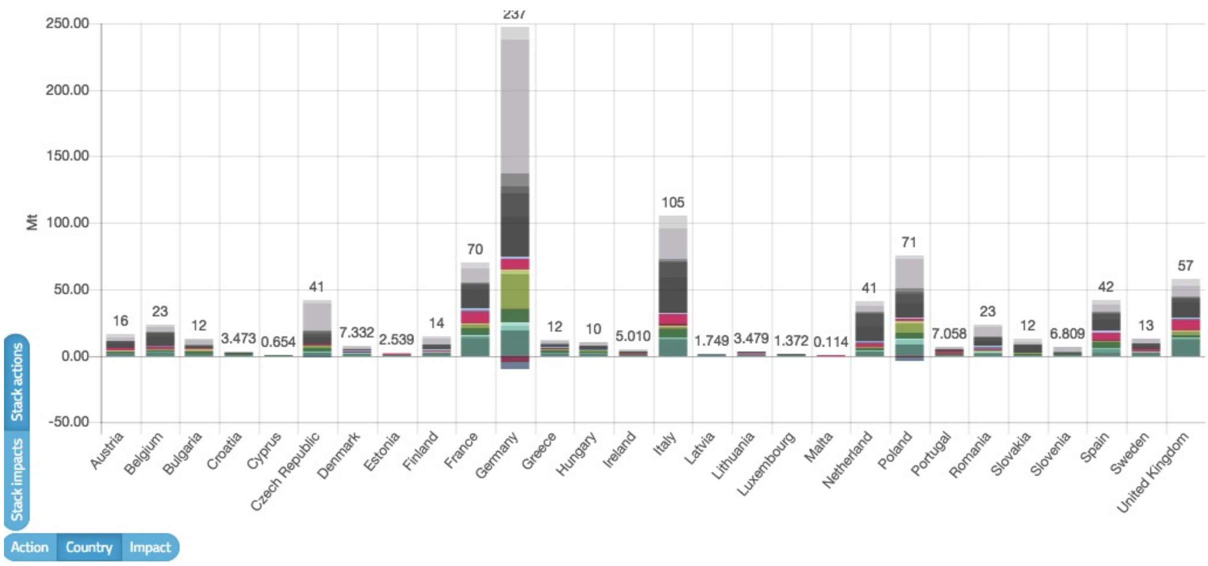
Energy efficiency is resource efficiency. More than 850 million tons (Mt) per year of material do not have to be permanently removed from nature, if Europe implements all COMBI EEI actions in all sectors.

This total reduction in material footprint can also be disaggregated to savings in metal ores, fossil fuels, minerals, biotic materials and economically unused extraction.

Yet, there are also resource costs. As an example from the transport sector, roughly 51 million tons of fossil fuels could be saved from improvements in the transport sector alone, but some additional 18 million tons of metal ores are required to provide the necessary transport systems of the future.

More details and full D4.4 quantification report

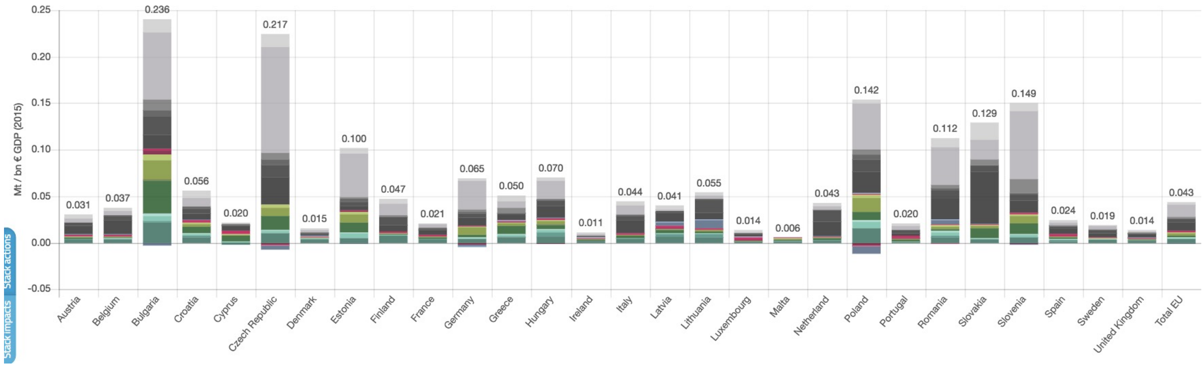
Figure 18: Reduction in material footprint in the EU-28 in Mt/year in 2030



View graph in COMBI tool

Total reduction in material footprint amounts to 850Mt/yr in the EU-28. Most resources can be saved from EEI actions in industry.

Figure 19: Avoided unused extraction resources in the EU-28 and the total EU in 2030 (Mt per bn€ of 2015 GDP)



[View graph in COMBI tool]

Key results

- especially high resource impacts in the Central and Eastern European Countries
- especially low resource impacts in Western European Countries

3.8 Energy system & security: Savings of more than 250 TWh/year of electricity generation and 10 bn€/yr of investments in combustion plants

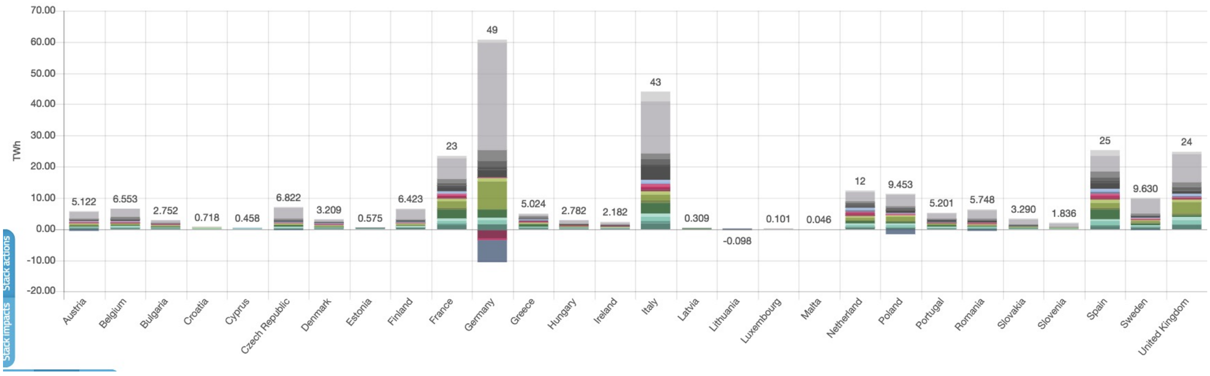
For analysing efficiency impacts on the energy system and energy security, the dedicated COMBI energy balance model was developed and applied. A number of relevant impact indicators were quantified:

- Energy intensity is reduced by up to 22 kgoe/1000€ GDP
- The COMBI Herfindahl-Hirschman Index (HHI) measuring energy security through import dependency, diversification of energy sources and geographical diversification improves by up to 5%
- Avoided generation of power from combustibles-based power plants amounts to 257 TWh in the EU and
- avoided investments to these power plants to around 10 bn€/yr.

De-rated reserve capacity rate (defined as the reserve capacity of the power sector, divided by its total installed capacity, multiplied by 100) improves in almost all EU countries.

D7.4 quantification report

Figure 20: TWh/yr of avoided electricity generation from combustibles-based power plants in 2030



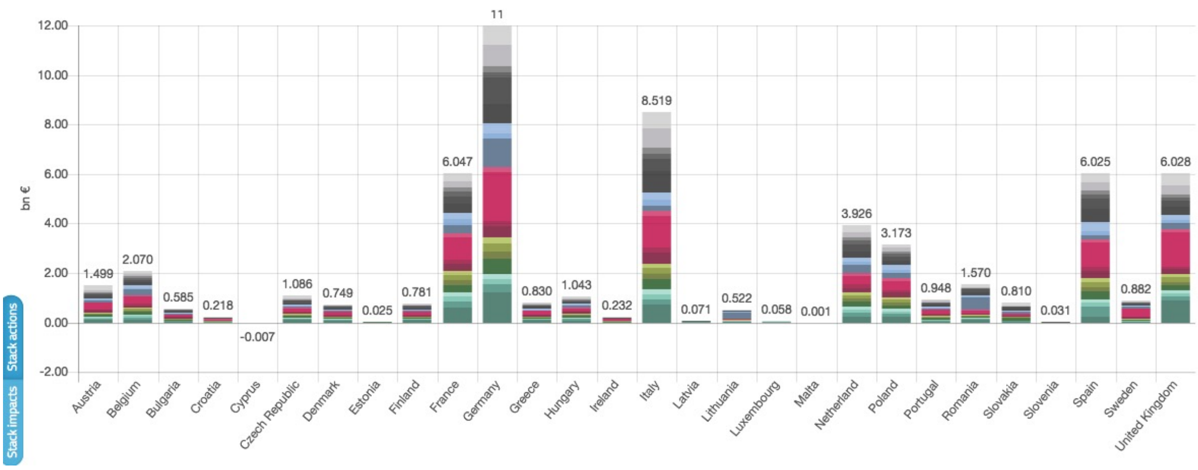
[View graph in COMBI tool (CBA graph, incl. colour legend)]

Note

- additional electricity demand in Germany (shown as negative savings) due to modal shift in passenger and especially freight transport sector

COMBI shows that the additional EEI actions in the COMBI EE scenario would help to reduce fossil fuel import costs from outside the EU by almost 60 bn €/yr in 2030 (for the total EU). In absolute terms, big effects occur in big countries, as Figure 21 shows. The highest per GDP effects occur in Central and Eastern European countries.

Figure 21: Avoided fossil fuel import costs from outside the EU in 2030



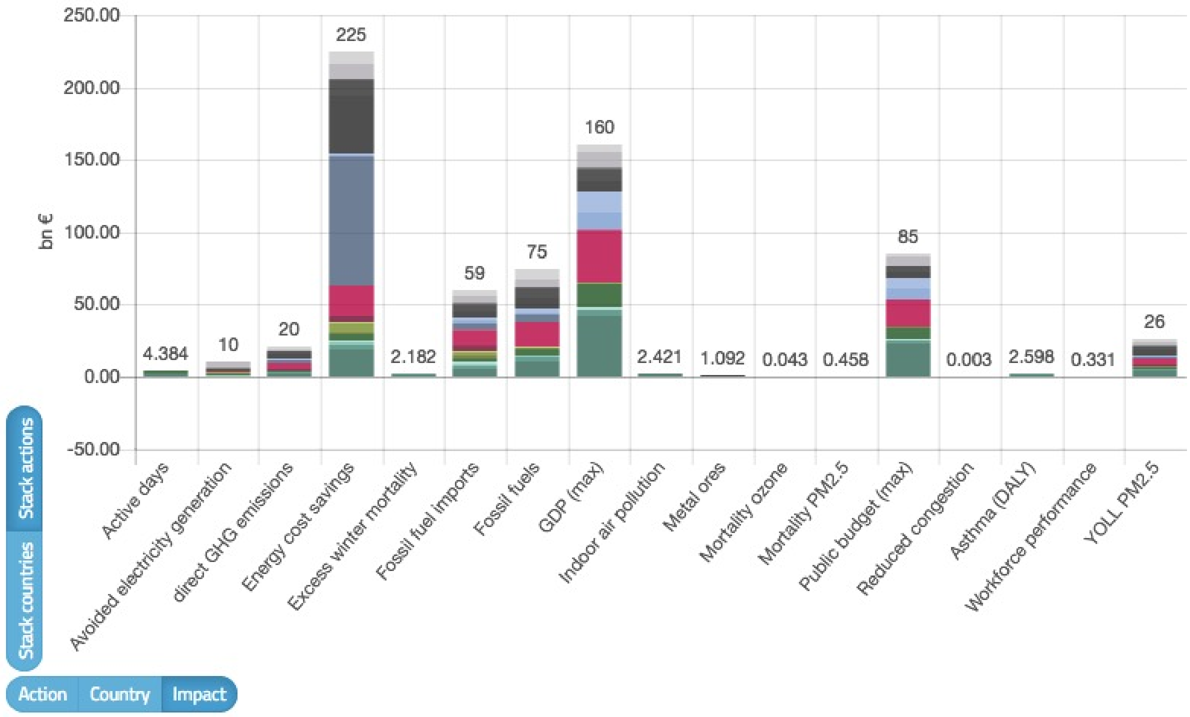
[View graph in COMBI tool (CBA graph, incl. colour legend)]

4 Insights from cross-impact analysis

4.1 Comparison of monetized impacts

As discussed above, not all impacts were possible to monetize. All those that could be monetized can be viewed and selected in the "monetary" mode of the tool, irrespective of possible double counting. Figure 22 illustrates all impacts in monetary values in bn € and disaggregated to monetized impacts for the "expert mode" of the tool.

Figure 22: Selected impacts that can be monetised (in bn €/yr in 2030) by impact



View graph in COMBI tool (incl. colour legend: EEI impacts)

View graph in COMBI tool (pre-aggregated version in standard mode)

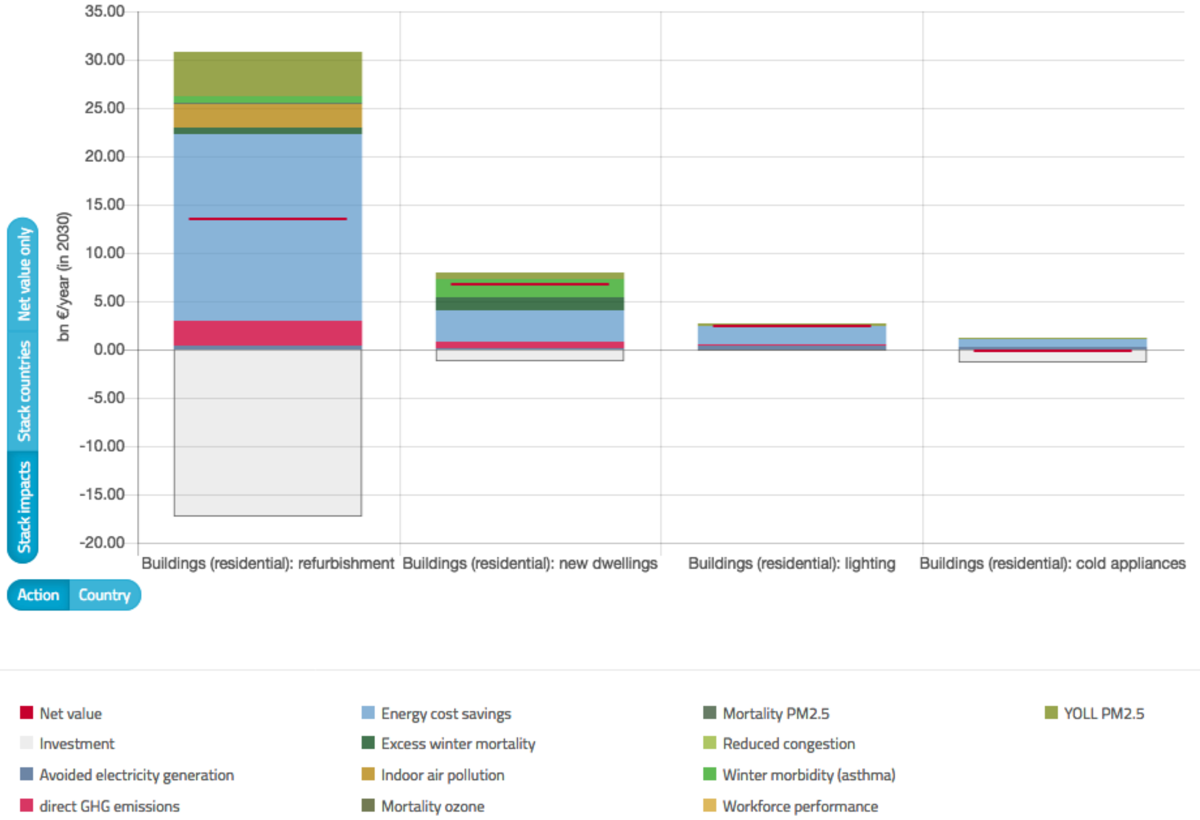
4.2 Cost-benefit analysis of COMBI EEI actions

As explained above, a significant number of (monetized) impacts overlap with each other or with direct energy cost savings, so possible double counting needs to be avoided. In COMBI, only impacts with no danger of double counting (i.e. *additional* impacts) are included in the Cost-benefit analysis and the respective mode in the tool. However, many impacts only partially overlap, i.e. are partially additional. Excluding them entirely as does COMBI is hence a very conservative approach.

Based on the user's selection of EEI actions, EU28-member states and impacts, the online tool will execute a calculation of net values resulting from costs (investments) and benefits (energy cost savings and multiple impacts). Details of the calculation are included in the tool documentation (D8.1). Figure 23 shows an example of annualised net present value (red thin line) for additional[19] EEI actions in the residential buildings sector in the EU28 member states.

19 Difference between COMBI reference and efficiency scenario.

Figure 23: Annualised net present value (bn€ per year in 2030) for the refurbishment of buildings in the residential sector[20]



View graph in COMBI tool

View graph in COMBI tool: all EEI actions (except modal shift which cannot be included to CBA due not no availability of infrastructure investment costs and excl. freight transport actions due to out-dated investment cost figures)

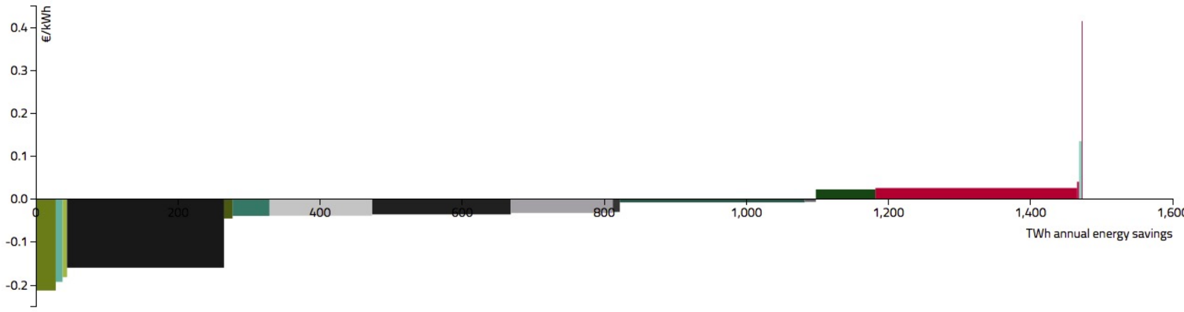
The online tool also offers levelisation of net values by TWh-savings and CO_2eq-savings, i.e. relating the net value per EEI action to energy and GHG emission savings. As a result, the tool offers for each action an indicator of

- net cost per kWh energy saved
- net cost per tCO_2eq mitigated

These are standard indicators often used for comparing energy saving options with energy supply options. Combining these indicators with the savings potential (total kWh or tCO_2eq) and ranking EEI actions by net marginal cost, they can be turned into marginal cost curves of energy or GHG emission savings (see Figure 24).

20 Mortality PM2.5 in Figure 24 refers to the number of premature deaths due to exposure to PM2.5 in 2030, while YOLL PM2.5 refers to the loss of the life expectancy to the surviving population due to exposure to PM2.5 in the year 2030.

Figure 24: Net marginal energy cost savings (total) by EEI action for EU28 in 2030 (*excluding* multiple impacts) (excluding modal shifts and trucks) (expert mode)



View graph in COMBI tool (incl. colour legend)

Note: Because *net costs* = *costs* – *benefits* → if *benefits* > *costs* then net costs are negative → EEI actions are cost effective.

Key results

- Without multiple impacts, already most EEI actions are cost-effective according to COMBI input data, except for the following:
  - Buildings (tertiary): refurbishment
  - Transport (passenger): cars
  - Transport (passenger): public roads/buses
  - Buildings (residential): cold appliances
  - Transport (passenger): two wheelers
- No analysis can be undertaken for modal shift and freight transport actions (see above)

Figure 25: Net marginal energy cost savings (total) by EEI action for EU28 in 2030 (*including* multiple impacts) (excluding modal shifts and trucks)

View graph in COMBI tool (all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of out-dated investment costs)

Key results

- Incl. multiple impacts almost all EEI actions included become cost-effective, except for
  - Buildings (residential): cold appliances (COMBI action is A+++ only)
  - Transport (passenger): two wheelers (costly action, but limited savings potential)

5 Conclusions and policy recommendations

5.1 Key results

Pursuing a more ambitious EE policy that leads to achieving the COMBI efficiency scenario relative to the COMBI reference will lead to **at least** the following impacts (conservative estimation, selected annual impacts in 2030):

Air pollution	Resources	Social welfare	Economy	Energy system
>10,000 avoided premature deaths due to $PM_{2.5}$ (460 mn €) and 442 due to O_3 (46 mn €) 230,000 YOLLs of avoided life expectancy loss (26 bn €) 300Mt avoided direct CO_2eq emissions (17 bn €)	850 Mt savings of material resources	3,000-24,000 avoided premature deaths due to indoor cold (323 mn €-2.5 bn €) 2,700-22,300 avoided DALYs due to indoor dampness related asthma (338 mn €-2.9 bn €) 39mn additional work-days (4.7 bn €)	1% rise in GDP (+161 bn € in GDP) 2.3 mn job-years +86 bn € for public budgets Decrease in fossil fuel prices (1.3% oil, -2% coal, -2.9% gas)	Avoided generation of power from combustibles 257 TWh (11 bn € of avoided investment) Improved energy security up to 5% lower fossil fuel import costs (48 bn €)
WP3 report	WP4 report	WP5 / WP5a report	WP6 report	WP7 report

Figure 26: Investments, energy cost savings and multiple impacts (bn€ annual in 2030)

[a] all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of out-dated investment costs

Figure 26 summarises the results. If including only those monetized impacts to a cost-benefit analysis where COMBI is entirely sure that no overlaps exist, the analysis yields that annually

- for all COMBI actions (excl. modal shift and trucks), MI amount to 61 bn€ vs. 131 bn€ of energy cost savings, i.e. MI are approx. 50% of energy cost savings
- for the residential buildings refurbishment example, MI amount 13.6 bn€ vs. 19.2 bn€ of energy cost savings, i.e. MI are approx. 70% of energy cost savings

Economic impacts (aggregate demand/GDP and public budget) are not included due to *partial* overlaps (that could not be quantified) and uncertain valuability (only effective, if economy with idle resources). However, those are the potentially highest impacts. The figure demonstrates, that

- For all actions (excl. modal shift and trucks), GDP may add value with the size of another 100% of energy cost savings, and public budget another 50%
- For residential buildings, this relation is even higher, namely 220% of energy cost savings GDP effect and 120% public budget effect

To conclude, the conservative cost-benefit analysis approach of COMBI as included in the online tool yields that at the very least, including MI quantifications to energy efficiency impact assessment would increase the benefit side by 50–70%. But this analysis excludes numerous impacts that could either not be quantified or monetized or where any double-counting potential exists. Only including the quantified economic impacts of GDP and/or public budget would double or triple the size of MI – but because of their double-counting potential and uncertain realisation (idle resources in national economies in 2030), they have not been included in the COMBI CBA.

With further research, especially on impacts that could not be quantified or monetized and on determining the size of overlaps, so that the *additional* fraction of impacts can be included to a CBA, it is very likely, that Multiple Impacts will increase to 100% or more of pure energy cost savings. In any case, the cost-effectiveness of EEI actions improves substantially from a societal perspective when including MIs.

5.2 Policy recommendations

The COMBI results show that the multiple impacts of energy efficiency are substantial. Evaluating them as comprehensively as possible – in physical and ideally in monetary terms – is essential for the following reasons:

- A more complete picture of the various (positive and negative) impacts of energy efficiency is a precondition for a more complete assessment of policy impacts on a number of policy targets. Reliable quantifications of multiple impacts will thus support policy makers to make the right choice in prioritising energy efficiency vs. expanding sustainable energy supply (incl. their multiple positive and negative impacts), but also in energy efficiency policy design and implementation, i.e. help selecting those instruments and targets that maximize social welfare.
- An omission of multiple impacts in cost-benefit analysis reduces the cost-effectiveness of EEI actions below their actual value and leads to an underinvestment (sub-optimal level) in energy efficiency from a societal perspective. The same is true if not all impacts are included or are underestimated. If multiple impacts are included into the assessment of policy scenarios, higher ambitions on energy efficiency targets are more cost-effective.

- Energy efficiency is a case not only for cost savings and GHG Mitigation but also for improvements in human health, environment, agriculture, and could have positive stimulating effects on the economy. Making more explicit the Multiple Impacts that concern policy targets of non-energy departments (e.g. health, social welfare, economy) may lead to a convergence of interest and may encourage inter-departmental and cross-sectoral co-operation in policy making to pursue common goals.
- Quantified values of multiple impacts will be beneficial for their communication and promotion to decision-makers, stakeholders and the general public in order to gain support for the implementation of respective energy efficiency policies and to increase the attractiveness of investments in energy efficiency for potential investors.
- Not the least, energy efficiency policy that helps achieve the potential will also be a good investment for the minister of finance: a budget surplus of annually up to € 85bn is much more than the necessary energy efficiency policy is likely to cost. The EU might consider (e.g. in the multi-annual financial framework and the implementation of the financial stability pact) that all member states are able to take this prudent investment in energy efficiency policy.

For theses reasons, a more complete consideration of multiple impacts in policy making is necessary. An important future goal should therefore be to improve the knowledge base and make an assessment of as many multiple impacts as possible the standard in policy evaluation (ex ante and ex post). For this, where complex multiple impact assessments are not viable, pragmatic methodological solutions e.g. standard methods and default values will be needed that address the underlying complexities such as nonlinearities in a reasonable way.

The below Table 3 lists more detailed and impact-specific policy recommendations that can be drawn from COMBI analyses.

Table 3: Impact-specific policy recommendations

Impacts	Policy recommendation
Resources	The impacts for material resource use and greenhouse gas emissions are significantly reduced by energy efficiency improvements. The size of the effects could be even further increased, if shifts towards electricity are accompanied by the decarbonisation of the electricity supply systems and higher material efficiencies in production and end-of-life are achieved (circular economy). Both strategies also mitigate the effects of the only resource risk: the higher demand for metals in Europe in order to provide the necessary technologies for an energy-efficient and low-carbon economy. For policy, this means an integrated strategy for decarbonisation, circular economy and energy conservation will yield the highest benefits.
Energy poverty, building refurbishment	One of the most important policy implications in the public health sector is that the human health co-benefits of energy efficiency policies will depend not only on the scope and extent of such policies but also on their societal redistribution effects. If the socially vulnerable are left out of the energy efficiency policy implementation due to affordability, the vast human health co-benefits will remain unrealized as energy poverty-related human health impacts only occur to the socially vulnerable. There are strong synergies to be achieved from the nexus of social policy, public health policy, air pollution policy and energy efficiency. Multiple benefits could be reaped if energy efficiency policies could be geared towards reaching out to the socially vulnerable who suffer disproportionately from unhealthy housing conditions. Social policy officers, health care professionals, local air pollution specialists could be at the forefront of identifying the socially vulnerable who could benefit the most from energy efficiency improvement actions. As European societies age, the problems of excess cold weather mortality and morbidity may become even more acute. Therefore, improving the energy efficiency of the building stock along with mobility policies may be the only long-term solution to these problems. Acceleration of energy efficiency policies should not overlook the importance of a technically sound retrofit bal-

	ancing well the levels of insulation with the need to ensure adequate ventilation. Increasing indoor air tightness levels associated with deeper levels of retrofit may contribute to emergence of mould associated with indoor dampness and cause asthma in housing where it was not found before. Supervision over the quality of retrofit services is essential to ensure that building retrofits are in line with public health standards.
Health from modal shift to active transport	It may be of high interest to policy-making to study more in detail the multiple impacts, especially health effects as a result of increased physical activity, that may come from a more ambitious modal shift scenario than the one studied in COMBI. In our project, the shift rates towards active modes of transportation (walking, cycling and also public transportation in combination with walking and cycling) were not high enough to show strong health effects, but in a more ambitious scenario, this may well be the case. The effects on road injuries may also become more prominent under more ambitious scenarios of modal shift.[21]
Productivity	Productivity impacts that result from health impacts in refurbished buildings are especially high or only occur, if buildings are refurbished to a "deep retrofit" level. From this finding results, that if these benefits should be reaped, policy needs to make sure that buildings are really retrofitted to a deep level.
Health from air pollution	COMBI research has demonstrated that significant air pollution-related human health co-benefits can be achieved focusing on end-use energy savings as a result of energy efficiency improvements. To maximize air pollution benefits, energy efficiency policies could target regions, cities, neighbourhoods that suffer disproportionately from this environmental risk currently. More research is needed to demonstrate the importance of end-use energy efficiency in achieving better air quality at a local level.
Macro-economic impacts	*In the short run*, the positive macro-economic stimulus on the economy caused by the COMBI action is substantial; however, this stimulus will only materialise in countries with idle resources that can support further growth, which is the case for about half the EU28 Member States in 2018. *In the long run*, the COMBI actions will have a positive impact on the economy as well and lead to a reduction in CO2 emissions and energy prices and consequently to an improvement in terms of trade. For energy efficiency policies that drive large investments, to have the highest positive impact on the economy, implementation should be upscaled in times of an economic downturn – especially, when policies are geared towards labour intensive actions such as e.g. building renovations. Consequently, such policies will contribute to stimulating the economy in a downturn instead of risking additional overheating in the economy.
Energy system	Energy efficiency most definitely leads to substantial reductions in the need for large-scale fossil fuel based and nuclear power plants, thus also avoiding the requirement for substantial fossil fuel imports from outside the EU. However, to avoid problems with system reliability as a result of an increasing reliance on renewables only, energy efficiency policies have to be accompanied by policies furthering the research into and implementation of cost-effective and efficient energy storage technologies. In addition to also promoting demand flexibility in the framework of local power and heat grids, current policies should be geared towards a far better understanding of the interactions between energy efficiency improvements and shifts in energy demand, as empirical data at the moment are sorely lacking.

5.3 Further research needs

Generally, we see further research needs that should also be in the interest of all policy makers in order to improve the knowledge base to take better-informed decisions.

The three-year research project COMBI with limited resources was not able to fully close all knowledge and methodological gaps on quantified multiple impacts. These include:

- Sectoral & EEI action coverage: While COMBI covers the sectors of building, transport and industry, they are not covered in all possible detail. The buildings sector e.g. lacks a detailed assessment of air-conditioning technologies and many appliances. The transport sector would need a deeper investigation of modal shift strategies and of especially freight

21 Depending on the quality of infrastructure for active modes of transportation and also compliance rate with driving regulations, the effect on health maybe both positive and negative. There may also be a difference in short-run and long run implications for road injuries. In the short run there may be an increase in road injuries due to inadequate infrastructure and non-compliance in driving safety, but in the long-run assuming infrastructure upgrades the number of road injuries may level off and decrease. The dynamics is highly dependent on the current state of infrastructure and adoption rates of active modes of transportation.

transport technologies. The industry sector is based on data from available studies but would need an expanded data base for more detailed assessment.

- Many impacts could not, or not comprehensively, be quantified, especially a number of health impacts where the evidence base is not yet sufficient. Also macro-economic impacts (especially public budget) would need a more detailed assessment. For estimating the resource impacts from the changes in production of energy efficiency goods and services, a better base of data is needed as well.
- Quantification techniques: any model is never at its final stage but can continuously be improved to better estimate impacts. Also, COMBI was not able to analyse feedback loops of impacts on others, overlaps and interactions. For this, either an Integrated Assessment Model or iterative runs of the various models would be needed.
- Another important issue is that changes in some impact values are dependent on their (absolute) levels. For instance, the marginal impact of air pollution reductions varies according to pollutant concentrations. This means that effects are non-linear and cannot be directly converted into elasticities. For COMBI results, this means that in a strict scientific sense, impacts are applicable only for COMBI scenarios (or very similar scenarios). Multiple model runs would be needed to assess sensitivities and eventually develop elasticity curves of impacts vs. changes in input values.
- Impact aggregation issues: almost half of monetised impacts have potential overlaps with other impacts. Ideally, these overlaps could be quantified for adjusting impact sizes and including them to cost-benefit analysis. In COMBI, these corrections were not possible (apart from one) due to time restrictions. This leads to the exclusion of almost half of the impact indicators. This concerns especially the very large economic impacts. Being able to quantify overlaps would increase (possibly double) the size of multiple impacts in monetary terms.
- COMBI input data is based on the state of knowledge and latest available data (input data: 2015) on EEI actions. Technology development and costs however are constantly evolving. New technologies emerge and decrease sometimes dramatically in costs. It can be expected, that a cost-benefit analysis in the year 2030 would look much more favourable than the current COMBI state. In the case of light/heavy duty trucks, latest developments of investment costs (substantial, but non-quantifiable decrease) led us to exclude them entirely from cost-benefit analysis.

References

Cambridge Econometrics, Ernst & Young and SQ Consult (2017). The macro-level and sectoral impacts of Energy Efficiency policies. https://ec.europa.eu/energy/sites/ener/files/documents/the_macro-level_and_sectoral_impacts_of_energy_efficiency_policies.pdf

Copenhagen Economics (2016). Multiple benefits of energy renovations of the Swedish building stock. https://www.copenhageneconomics.com/publications/publication/multiple-benefits-of-energy-renovations-of-the-swedish-building-stock

Cox, E., Royston, S., & Selby, J. et al. (2016). The impacts of non-energy policies on the energy system: a scoping paper. https://www.academia.edu/30027209/The_impacts_of_non-energy_policies_on_the_energy_system_a_scoping_paper

EED – Energy Efficiency Directive. 2012/27/EU. http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX:32012L0027

EPBD – Energy Performance of Buildings Directive. 2010/31//EU. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN

European Commission (2016). Commission staff working document Impact Assessment Accompanying the document „Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency" SWD/2016/0405 final - 2016/0376 (COD)

Fawcett, T., & Killip, G. (2017). INBEE Project: D2.4 Intangible benefits of energy efficiency, final report. DOI 10.13140/RG.2.2.30825.49762. https://www.researchgate.net/publication/317345953_INBEE_Project_D24_Intangible_benefits_of_energy_efficiency_final_report

IEA – International Energy Agency (2014). Capturing the Multiple Benefits of Energy Efficiency. http://www.iea.org/publications/freepublications/publication/Multiple_Benefits_of_Energy_Efficiency.pdf

Renovate Europe (2012). Multiple benefits of investing in energy efficient renovation of buildings. http://renovate-europe.eu/Multiple-Benefits-Study/

Suerkemper, F., Thema, J., Thomas, S., Dittus, F., Kumpaengseth, M., & Beerepoot, M. (2016). Benefits of energy efficiency policies in Thailand: an ex-ante evaluation of the energy efficiency action plan. *Energy Efficiency*, *9*(1), 187-210.

COMBI references

D2.2 – Couder, J. (2018). Description of end-use energy efficiency improvement actions in the residential, tertiary, transport and industry sectors. Main report and Annex. https://combi-project.eu/wp-content/uploads/D2.2_20180322_final.pdf

D2.4 – Chatterjee, S., Ürge-Vorsatz, D., Thema, J., Kelemen, A. (2018). Synthesis methodology. https://combi-project.eu/wp-content/uploads/D2.4_20180515_final.pdf

D2.7 – Thema, J., Rasch, J. (2018). Quantification report (summary of quantifications, methodologies and introduction to results). https://combi-project.eu/wp-content/uploads/D2.7_COMBI_quantification_report.pdf

D3.4 – Mzavanadze, N. (2018). Quantifying air pollution impacts of energy efficiency. https://combi-project.eu/wp-content/uploads/D3.4_20180514.pdf

D4.4 – Teuber, J., Kiefer, S., Bienge, K. (2018). Methodology and quantification of resource impacts from energy efficiency in Europe. https://combi-project.eu/wp-content/uploads/D4.4_20180321_final.pdf

D5.4 – Mzavanadze, N. (2018). Quantifying energy poverty-related health impacts of energy efficiency. https://combi-project.eu/wp-content/uploads/D5.4_20180514.pdf

D5.4a – Chatterjee, S., Ürge-Vorsatz, D. (2018). Quantification of productivity impacts. https://combi-project.eu/wp-content/uploads/D5.4a_20180508a_final.pdf

D6.4 – Naess-Schmidt, S., Westh Hansen, M. B., Wilke, S., Lumby, B.M., (2018). Macro-economic impacts of energy efficiency. https://combi-project.eu/wp-content/uploads/D6.4_20180322_final.pdf

D7.4 – Couder, J. (2018). Quantification and monetization of selected energy system and security impacts. https://combi-project.eu/wp-content/uploads/D7.4_20180406_final.pdf

D8.1 – Thema, J. (2018). Online tool manual & documentation (incl. technical details & CBA formulae). https://combi-project.eu/wp-content/uploads/D8.1_tool-guide.pdf

Annex

Table 4: Inclusion of impacts to COMBI CBA

Work package	Impact end-point	Inclusion/ exclusion to CBA	Reasoning
WP3	Human health	✓	Existing overlaps with productivity accounted in WP5
	Eco-systems: acidification	✗	not monetized
	Eco-systems: eutrophication	✗	not monetized
	Air pollution: Emissions(mid-points)	✗	not monetized
WP4	Material Footprint (sum abiotic & biotic & unused)	✗	Full overlap with investment costs (material inputs part of production costs)
	Life-Cycle wide fossil fuel consumption (additional to direct combustion)	✗	Full overlap with investment costs (material inputs part of production costs)
	Metal Ores	✗	Full overlap with investment costs (material inputs part of production costs)
	Minerals	✗	not monetized
	Biotic raw materials	✗	not monetized
	Unused extraction	✗	not monetized
	Direct carbon emissions	✓	No overlaps with other impacts
	Carbon Footprint (lifecycle emissions incl. direct emissions)	✗	not monetized
WP5	Excess winter mortality attributable to inadequate housing	✓	No overlaps with other impacts
	Excess winter morbidity attributable to inadequate housing	✓	No overlaps with other impacts
	Indoor dampness/asthma	✓	Overlaps with outdoor air pollution accounted in dedicated quantification
	Active days (sick days ,DALY and avoiding road congestion) due to various diseases	✓	Overlaps with outdoor air pollution accounted in dedicated quantification
	Workforce Performance	✓	No overlaps with other impacts
WP6	Temporary (business-cycle) GDP effects	✗	Overlaps with energy costs, investments and potentially all multiple impacts
	Temporary (business-cycle) employment/GDP effects	✗	not monetized
	Temporary (business-cycle) public budget effects	✗	Rather analysable as separate evaluation perspective, not aggregable in CBA
	Fossil fuel price effects*	✗	quantified only at EU level
	ETS price effect*	✗	quantified only at EU level
	Terms of Trade effect*	✗	quantified only at EU level
WP7	Energy intensity	✗	not monetized
	Import dependency	✗	not monetized
	Aggregated energy security index	✗	not monetized
	Avoided electric power generation & investment costs	✓	no overlaps
	Derated reserve capacity rate	✗	not monetized

Table 5: Summary of results from COMBI quantifications

Impact category	Key findings of COMBI EEI actions in the EU28: annual impacts, additional values, difference between the two scenarios in the year 2030)	Detailed findings
Energy	Energy savings vs. the reference scenario: around 8%, 1647 TWh/year or 142 Mtoe/year in 2030 (around the "EUCO+33 to +35" scenario)	Energy savings in EU28: highest in Germany (307 TWh), Italy (227 TWh), France (192 TWh) Energy savings by actions: highest from transport: passenger cars (283 TWh), buildings (residential): refurbishment (260 TWh), industry: high temperature processes (220 TWh)
	Energy cost savings: 225 bn€ in 2030	Energy cost savings in EU28: highest in Germany (43 bn€), France (26 bn€), Italy (20 bn€) Energy cost savings by actions: highest from transport (freight): model shift (90 bn€), industry: high temperature processes (39 bn€), transport: passenger cars (20 bn€), buildings (residential): refurbishment (19 bn€)
	Investment cost: 1,072 bn€ [22]	Investment in EU28: highest in Germany (217 bn€), France (149 bn€), Italy (132 bn€) Investment by actions: : highest in transport: passenger cars (331 bn€), buildings (residential): refurbishment (302 bn€), buildings (tertiary): refurbishment (109 bn€)
Air pollution	Avoided PM2.5 emissions in 2030 in EU-28: 65.5 ktons per year Avoided PM10 emissions in 2030 in EU-28: 78.3 ktons per year	Countries with especially high PM2.5 avoidance: Italy, Poland and the UK, followed by the largest countries France and Germany. In Italy 9,200 kt PM2.5 could be avoided, half of the EEI actions are in the industry sector. In other EU countries, avoided PM2.5 emissions are more evenly distributed between sectors.
	Avoided SO2 emissions in 2030 in EU-28: 210.9 ktons per year	Avoided SO2 emissions (per GDP): highest in EEU countries; especially low in WEU countries; highest in Bulgaria due to actions in the transport and industry sector
	Avoided VOC emissions in 2030 in EU-28: 170.5 ktons per year	Avoided VOC emissions (per GDP): especially high in Eastern European and Baltic Countries; highest in Latvia, Bulgaria, Slovenia, Estonia
	Avoided NOX emissions in 2030 in EU-28: 316.9 ktons per year	
Ecosystem degradation	Area affected by acidification: additional 4.4 thousand km2 spared (additional reduction of 4%)	Largest area affected by reduced acidification in Sweden, Poland, Germany
	Area affected by eutrophication: Additional 13.3 thousand km2 spared (additional reduction of 1%)	Largest area affected by reduced eutrophication in Italy, France, Austria, High avoided eutrophication effects (per GDP): in Estonia due to different EEI actions especially in the buildings and transport, but also in the industry sector
Energy system/ security	Energy intensity: reduced by up to 22 kgoe/1000€ GDP	Energy intensity improvements relative to the reference case for the EU member states vary from roughly 10% to 15%, reflecting the different energy savings similar COMBI actions may realize in the different countries.
	COMBI HHI index (measuring energy security through import dependency): diversification of	Some EU member states improve their energy security as a result of the COMBI actions, while others appear to be worse off,

22Investment costs for all EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of outdated investment costs.

	energy sources and geographical diversification improves by up to 5%	mainly due to decreased net diversification effects.
	Avoided generation of power from combustibles-based power plants: 257 TWh in the EU; avoided investments to these power plants: around 10bn €	Avoided electricity generation from combustibles-based power plants: additional electricity demand in Germany due to modal shift in passenger and especially freight transport sector Only in Lithuania slightly higher costs for combustibles-based power plants (4 Mio. €) due to an increase in gas based powered plants, all other EU countries benefit (avoided costs) due to a decrease in required generation capacity.
	De-rated reserve capacity rate (defined as the reserve capacity of the power sector, divided by its total installed capacity, multiplied by 100): improves in most EU countries	Note: For EU member states with an already fairly high reserve capacity rate, an increase may not be optimal from an economic point of view.
	Monetized avoided fossil fuel imports from outside EU: reduced fossil fuel import costs from outside EU by almost 60 bn € (for the total EU).	In absolute terms, large effects occur in big countries. The highest per GDP effects occur in Eastern European countries.
Labour productivity	Gain of 4.5 active work days/person per annum by having more deeply retrofitted buildings, passive houses, and nearly zero energy buildings	
	By improving the mental well-being an European country can on average gain around 15.7 million €/year and 1961 healthy life years per million population per annum by avoiding exposure to bad indoor air quality and conditions	
	By opting for modal shift towards active transportation, 1.6 hours/driver can on average be saved from traffic congestion per year	
Mortality	Avoided premature mortality due to PM2.5: additional 10,805 premature deaths avoided in the EU-28 due to reduced exposure to particulate matter, monetary value of avoidable mortality: 460 million EUR exposure in 2030 for the EU-28	Number of avoided yearly deaths (in 2030) due to avoided PM2.5 exposure highest in Italy, Germany, UK, France
	Avoided life expectancy loss due to PM2.5 to the surviving population in 2030: 230,226 YOLLs and immense 26.41 billion EUR for the EU-28	Avoided life expectancy loss due to PM2.5 highest in Italy, Germany, France
	Ground level ozone: additional 442 deaths would be avoided due to reduced ozone exposure, monetary value of avoidable mortality: 46 million EUR due to reduced ground level ozone exposure in the year 2030 for the EU-28	Number of avoided yearly deaths (in 2030) due to reduced ozone exposure highest in in Italy, Germany, United Kingdom, France
	Avoided excess cold weather deaths due to indoor cold exposure: 3,000–24,000 avoided premature deaths	
Climate	Avoided Carbon Footprint: 509 Mt CO2eq of reduced global GHG emissions	Especially high impacts per GDP in Eastern European countries high impacts per 2015 GDP from transport and industry sector
	Avoided direct GHG emissions in the EU (from fuel combustion): 362 Mt CO2eq annually	Especially high impacts per GDP in Eastern European countries high impacts per 2015 GDP from transport and industry sector

Health/morbidity	In total, 281,000 DALYs could be gained.	The aggregated total DALY (healthy life years) figures from different impact chains (health from better building indoor conditions, from outdoor air pollution and polluted air infiltrating indoors) indicate that EEI actions with high savings of fossil fuels have a strong impact, most prominently building refurbishment and transport, but also industry actions.
	Winter morbidity (asthma): 2,700–22,300 disability-adjusted life years (DALYs) of asthma morbidity can be avoided due to indoor dampness	
	Economic value of avoided annual public health damage in 2030: 338 million EUR to of 2.9 billion EUR due to asthma morbidity due to indoor dampness	
Macro-economy	Short run positive macro-economic stimulus on the economy: 0.9 per cent of EU's GDP and a positive effect on the labour market of 2.3 mn job-years. This stimulus will only materialise in countries with idle resources in 2030 that can support further growth (negative output gap, situation of economic downturn). In 2018, about half of the EU28 Member States are expected to have a negative output gap.	Short-term increase in GDP for the EU28: mainly induced from buildings and actions in the transport sector (actions with high investment values) Largest number of jobs: from EEI actions with high investment values and implemented in labour-intensive sectors: buildings (residential and tertiary) and transport sector Total employment and GDP effects: larger for bigger countries Increase in GDP as % of GDP: especially Eastern European Countries see larger GDP increase
	Long run effects: CGE modelling shows no significant impacts on employment and even slightly negative impacts on GDP. Reduction in CO2 emissions and significantly lowered carbon allowance and fossil fuel prices due to EE improvements, which, given all EU countries are net fossil fuel importers will also improve their terms of trade.	Fossil fuels prices in the EU: decrease by 1-3% compared to a current policies scenario Global price on crude oil: falls by 1% Coal and gas prices in the EU: reduced by 2% and 3% respectively
	Public budget effect: While public investment or subsidies imply higher public spending, there is also potential for cost savings with improved EE in the public sector. In addition, the employment and output effects mentioned above bring about an increase in tax revenue	Public budget effect (in absolute terms): highest in the larger EU countries France, Germany, Italy, Spain and the United Kingdom Public budget effect (expressed per GDP): more evenly distributed among EU28, rather high for EEU countries, and lower for CEU countries Public budget effect in 2018: range from 0.06% (Bulgaria) to 0.56% (Finland) of GDP. Public budget effect in 2030: largest in the Netherlands, Italy and Portugal with 0.64% of GDP in all these countries (assuming a sufficiently negative output gap in all countries). Smallest budget effect in Luxembourg and Greece with less than 0.3% of GDP
Resources/ material footprint	Material Footprint: net savings of 868 Mt of materials	Avoided unused extraction resources per bn€ of 2015 GDP: especially high in the Eastern European Countries (highest in Bulgaria and Czech Republic), especially low in WEU countries
	Differences in the production systems (production phase) for vehicles and lighting systems require additional 11.2 Mt of resources (partial use phase compensation), but also lead to additional Carbon Footprint savings of 8.7 Mt (overall savings).	